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A1R214A A1R214H A1R214U A1R314C1D A1R314C1F  
A1R420 A1R432 A1R454A A1R454B A20T1  
A5R RAG RD1

(56) Documents Cited:

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EP 0962215 A2 EP 0205333 A1  
IE 920000833 A JP 630279835 A

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UK CL (Edition V) A5R, B5A  
INT CL<sup>7</sup> A61K  
Other: ONLINE: WPI, EPDOC, JAPIO.

(54) Abstract Title: **Calcium phosphate -synthetic resin -metal composite body and method of production thereof**

(57) A calcium phosphate-synthetic resin-metal composite body produced by pressing a metal member 200, calcium phosphate particles 100 (or calcium phosphate particles and a calcium phosphate block 300) and synthetic resin particles I, which are at least partially cross-linked in advance, uncross-linked, synthetic resin particles II while heating, the calcium phosphate particles and/or the calcium phosphate block being exposed on at least part of the surface of the composite body. It is produced (Fig 16-20) by (a) introducing a metal member, calcium phosphate particles (or calcium phosphate particles and calcium phosphate block), and synthetic resin particles I and II into a cavity 2a of a molding die 2 such that the synthetic resin particles surround the calcium phosphate particles, and that the calcium phosphate block, if any, is exposed on at least part of the composite body surface; and (b) pressing them in the molding die cavity while heating, so that the synthetic resin particles are bonded to the metal member and the calcium phosphate particles (or the calcium phosphate particles and the calcium phosphate block). The article is preferably for medical or dental use and may include a screwed end (fig 15). The metal can be a cylinder or tube, can have windows or be a mesh or apertured plate, etc.

Fig. 1(b)

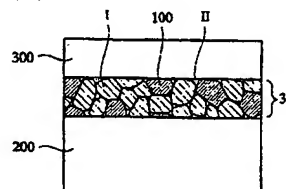
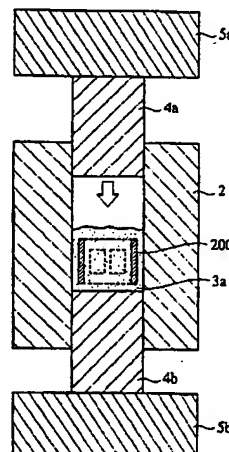


Fig. 20(b)



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Fig. 1(a)

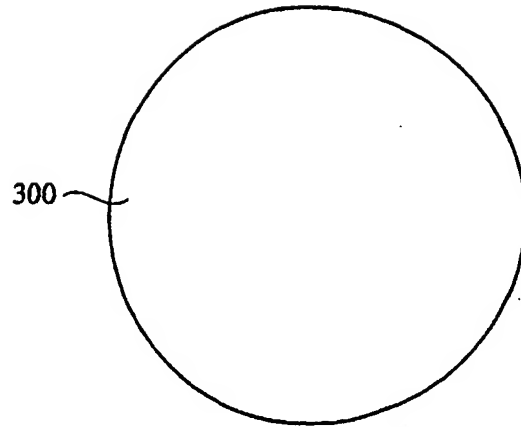


Fig. 1(b)

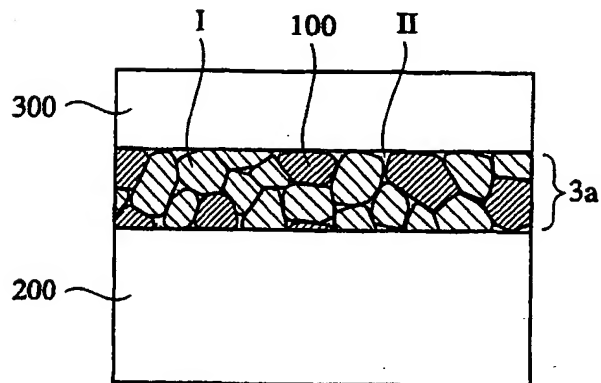


Fig. 2(a)

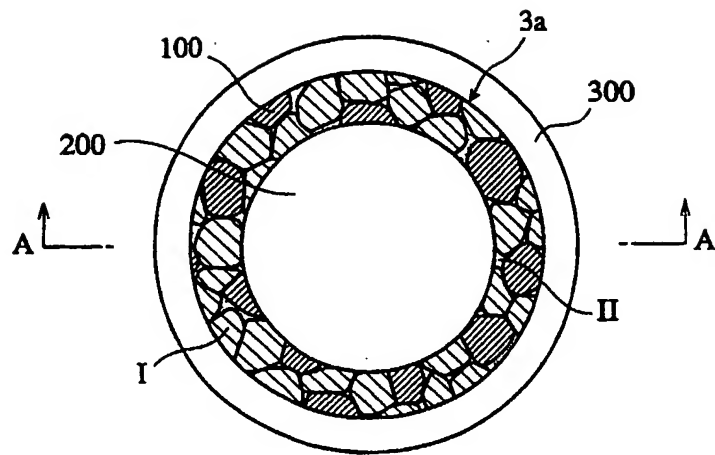


Fig. 2(b)

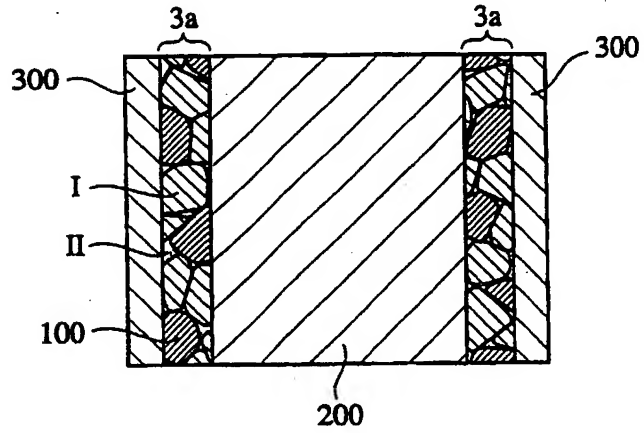


Fig. 3(a)

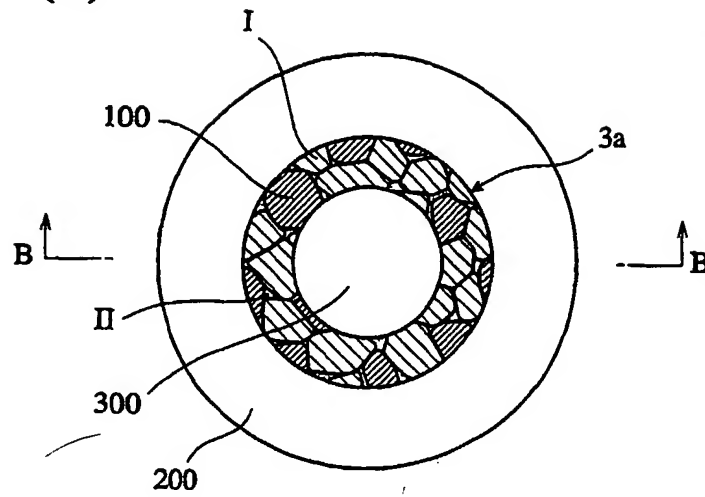


Fig. 3(b)

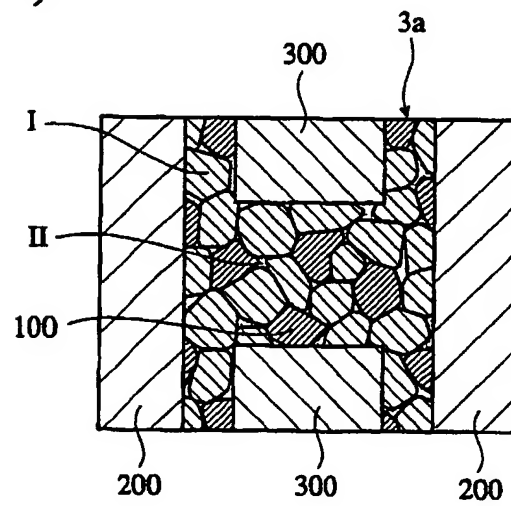


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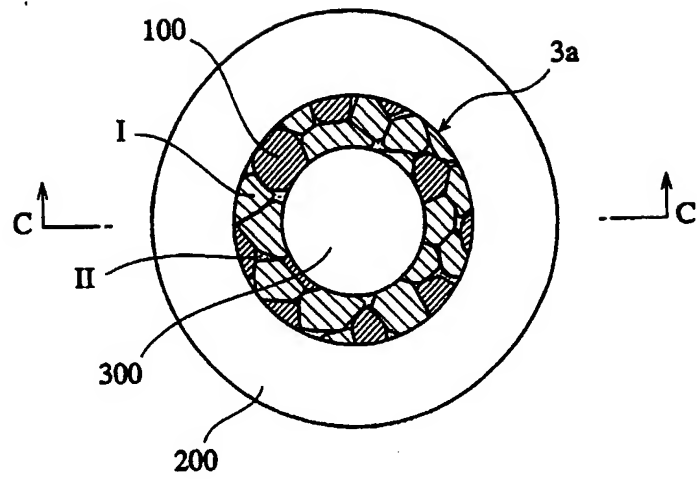


Fig. 4(b)

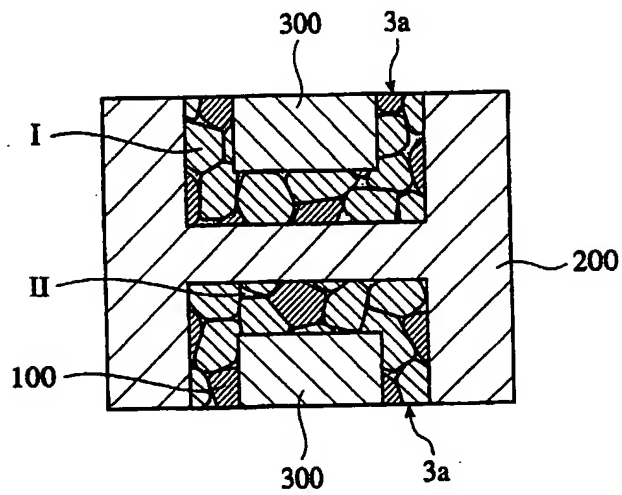


Fig. 5(a)

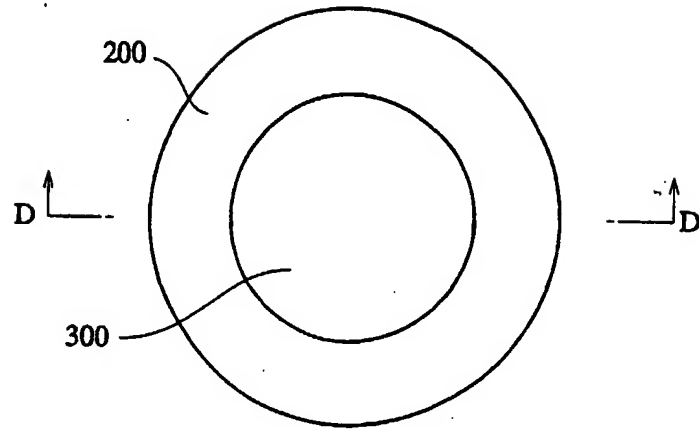


Fig. 5(b)

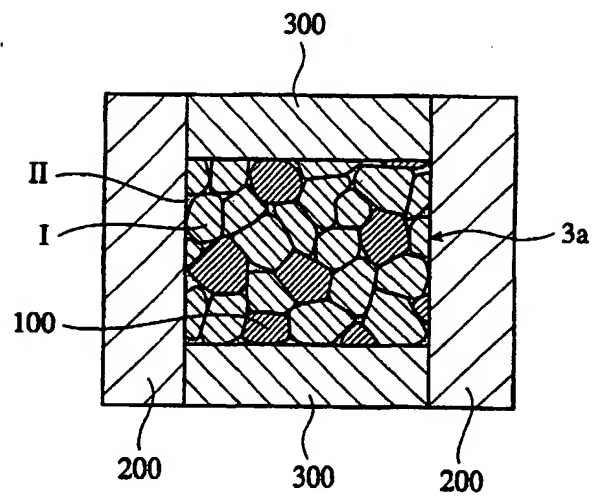


Fig. 6(a)

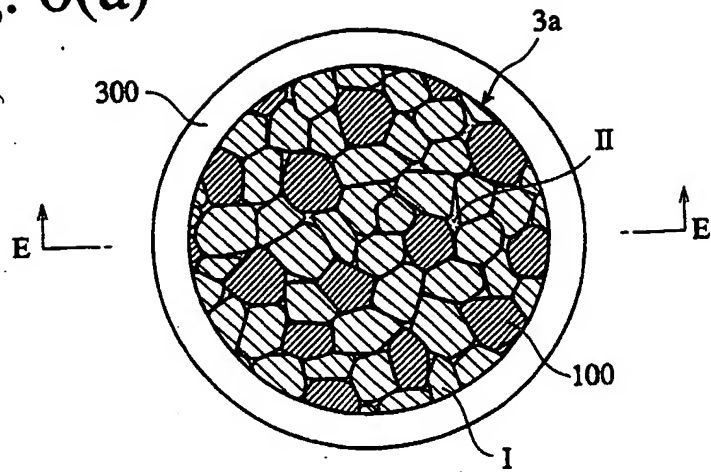


Fig. 6(b)

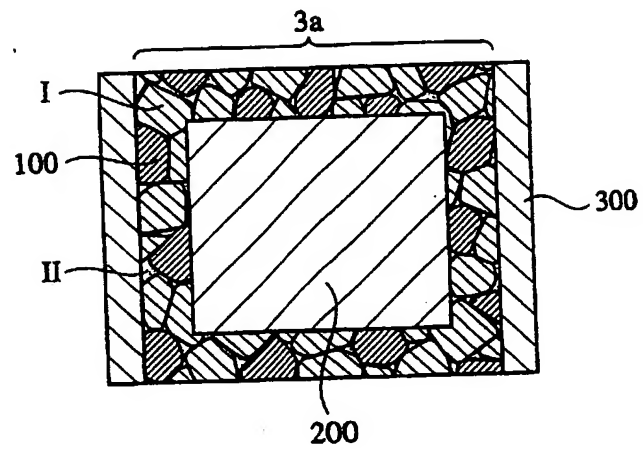


Fig. 7(a)

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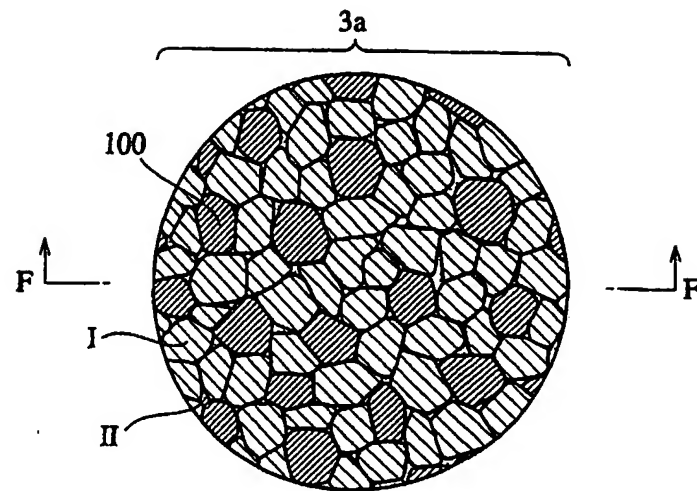


Fig. 7(b)

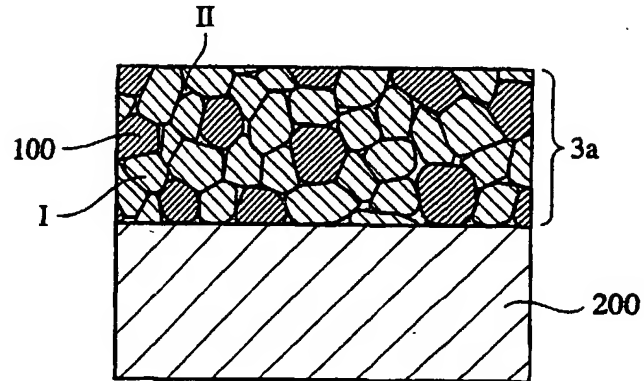


Fig. 8(a)

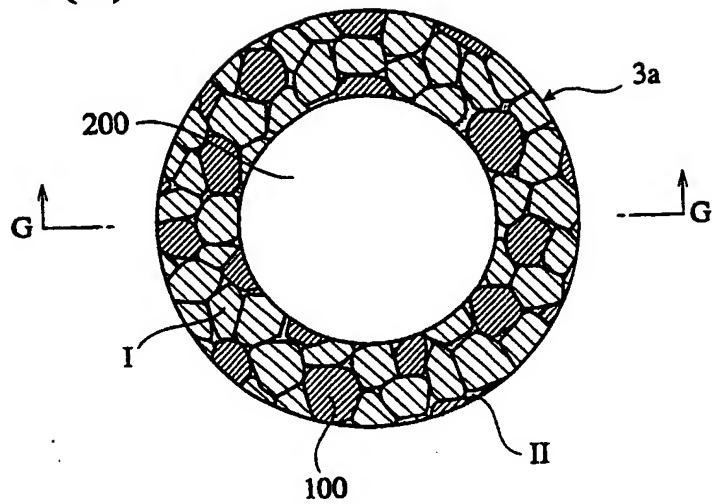


Fig. 8(b)

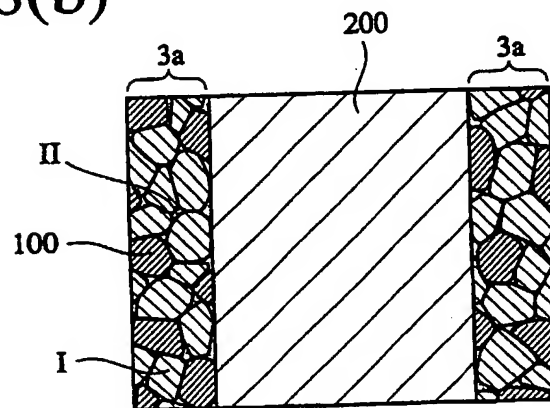


Fig. 9(a)

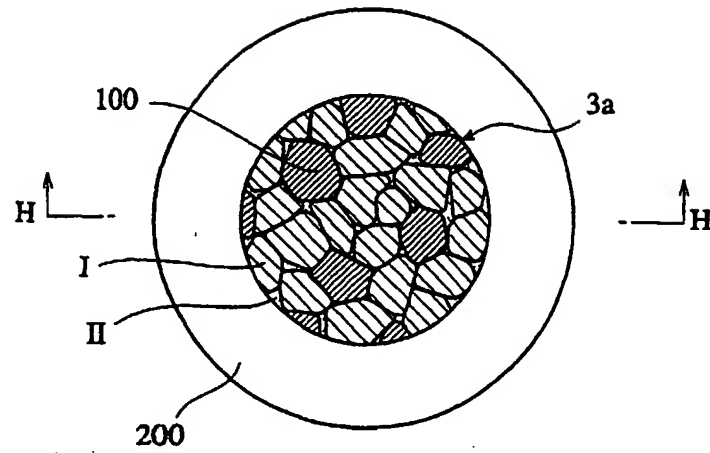


Fig. 9(b)

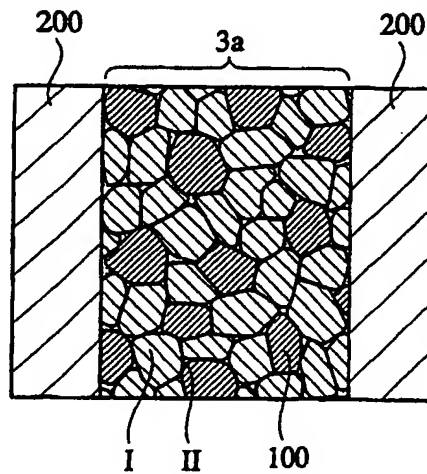


Fig. 10(a)

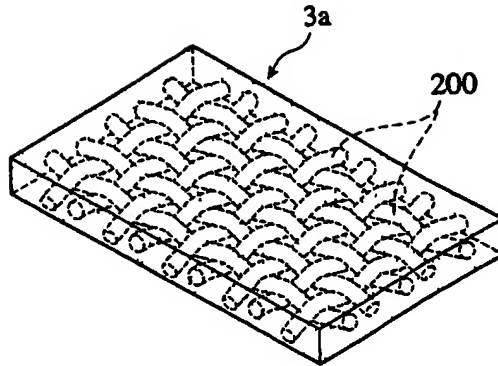


Fig. 10(b)

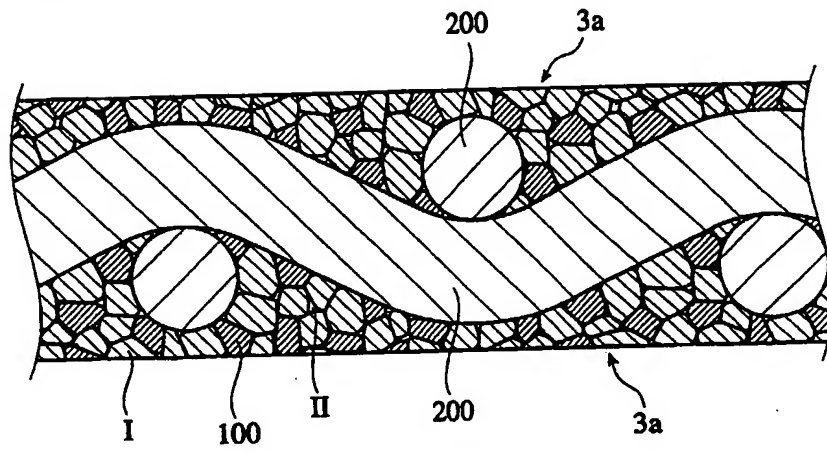


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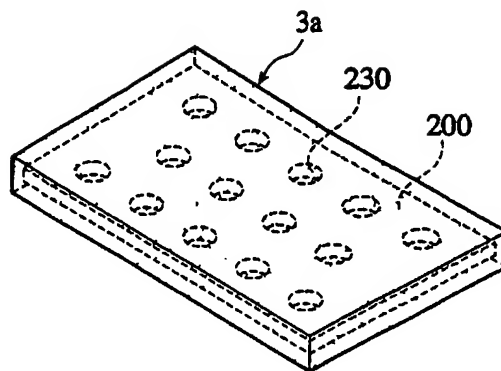


Fig. 11(b)

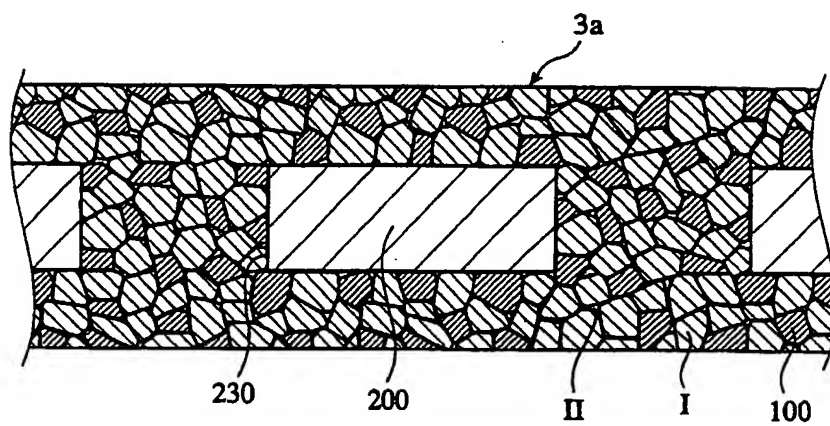


Fig. 12

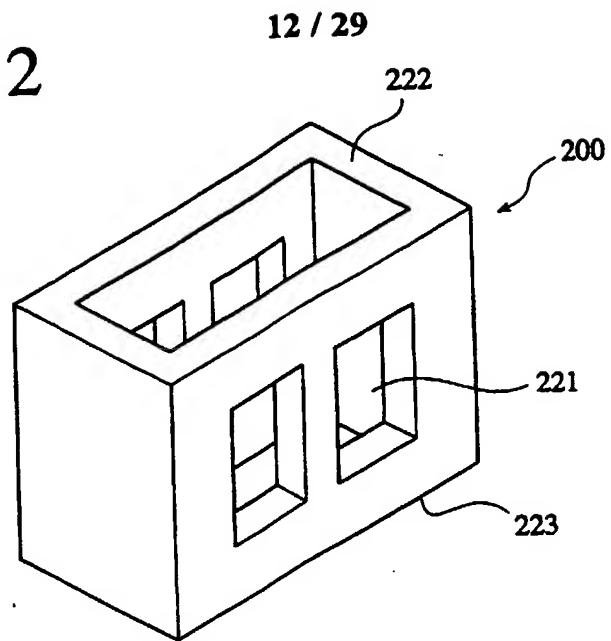


Fig. 13

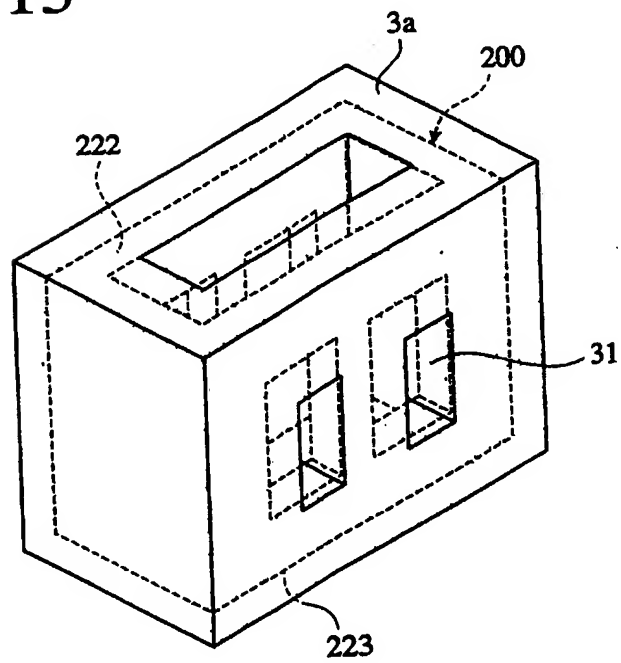


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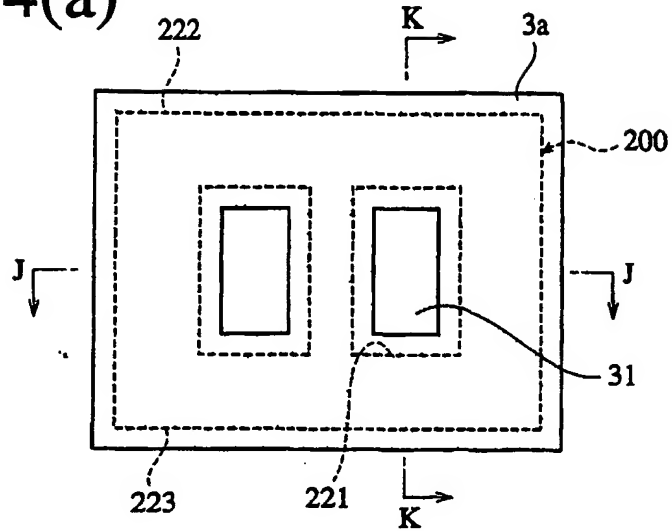


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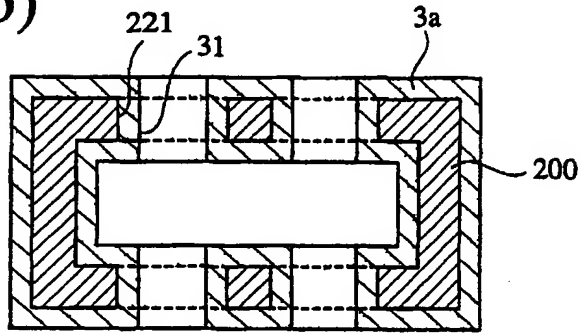


Fig. 14(c)

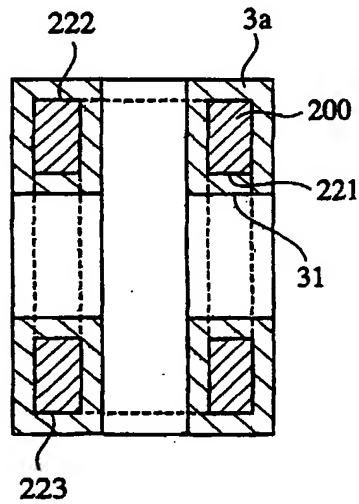


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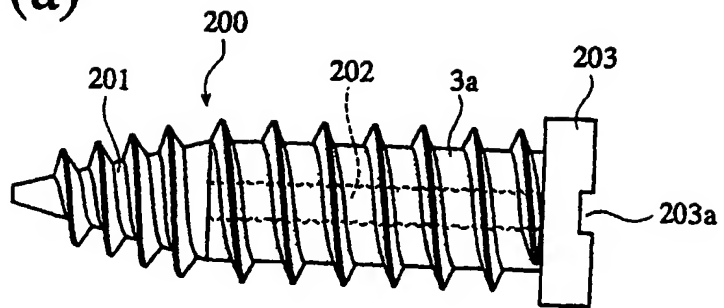


Fig. 15(b)

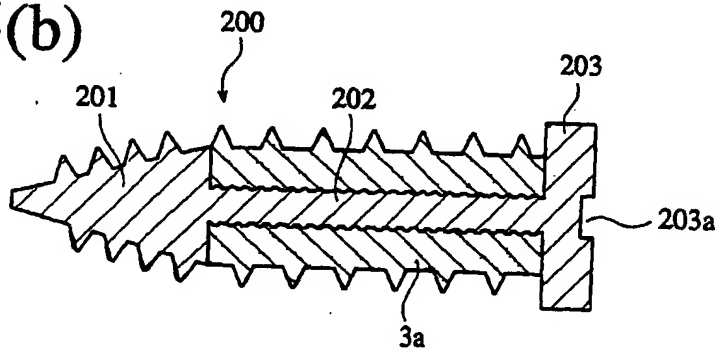


Fig. 16

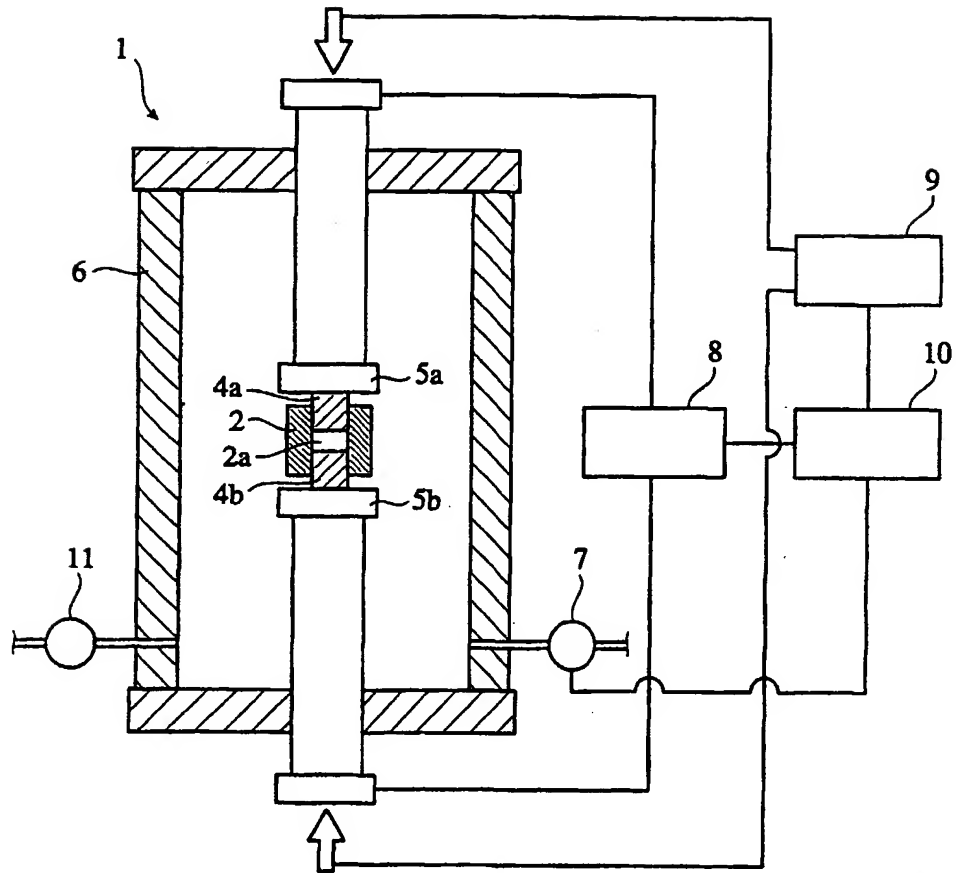


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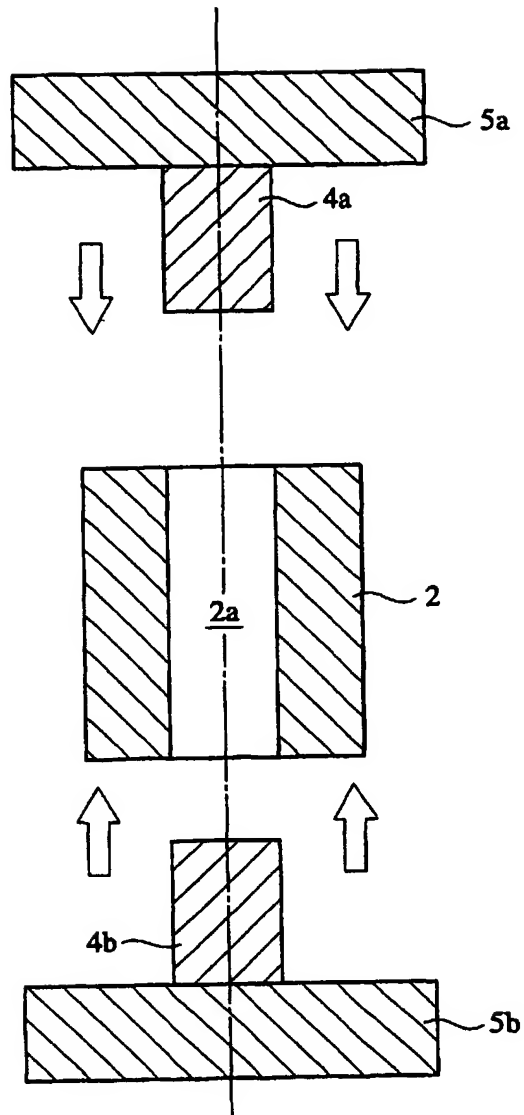


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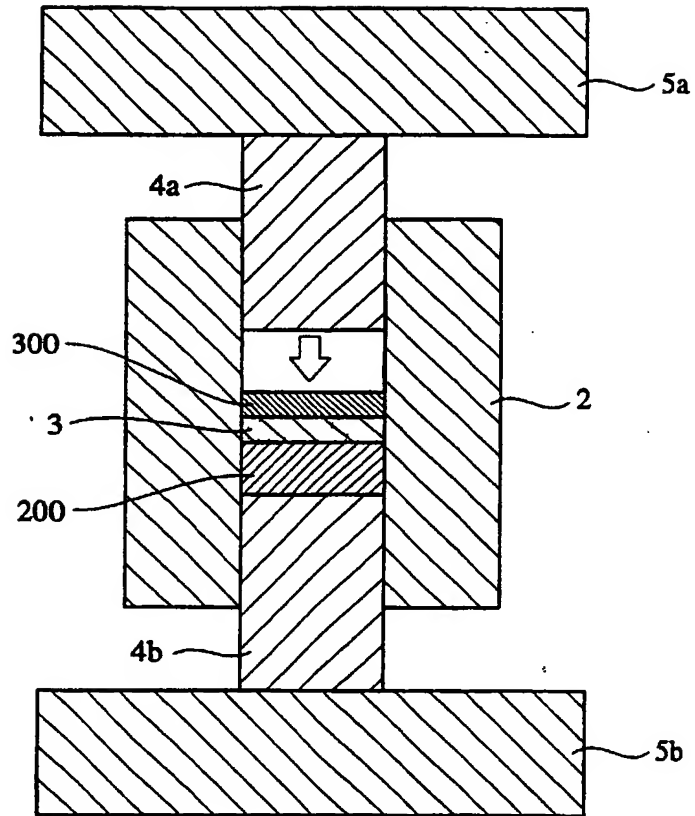


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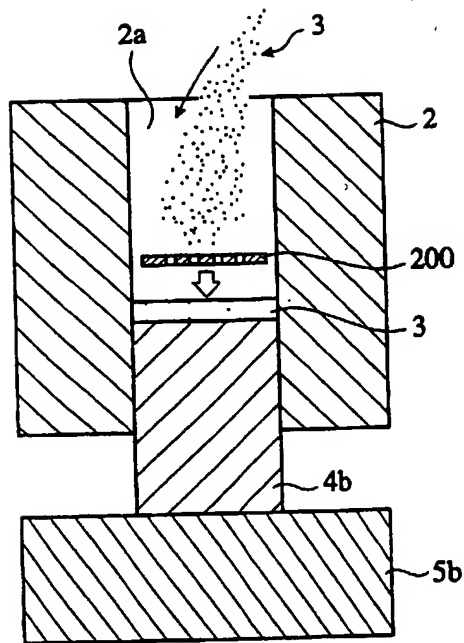


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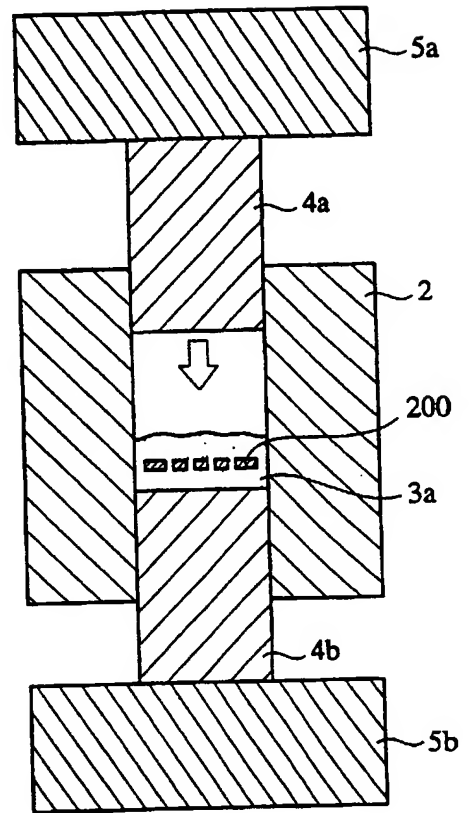


Fig. 20(a)

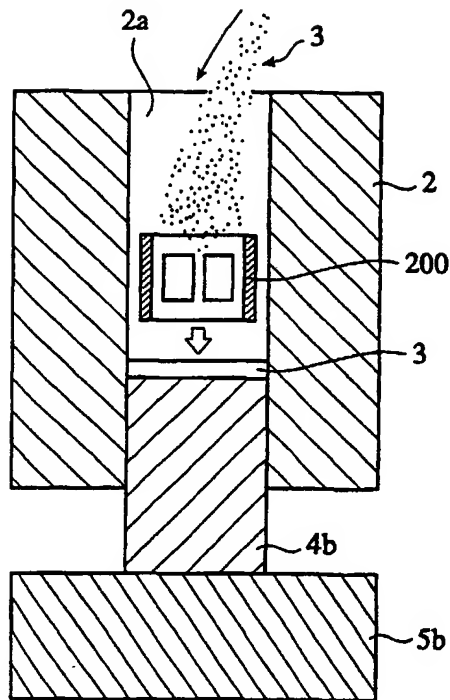


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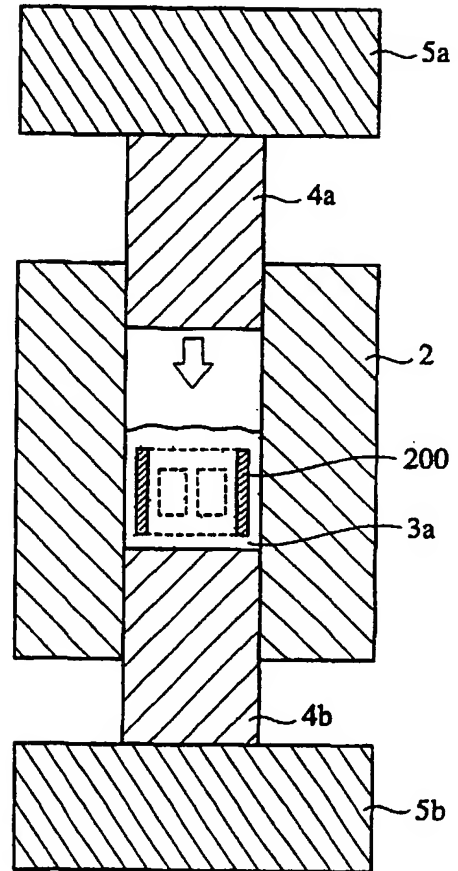


Fig. 21

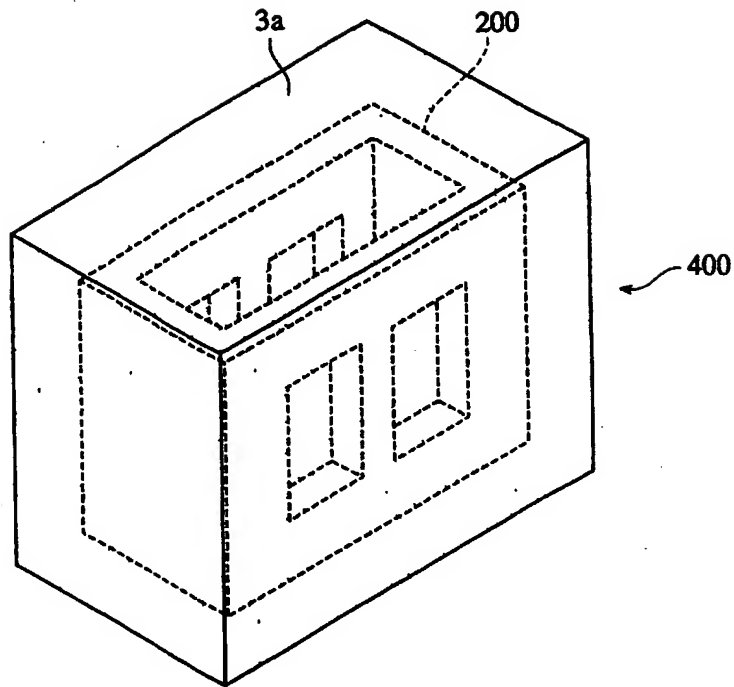


Fig. 22(a)

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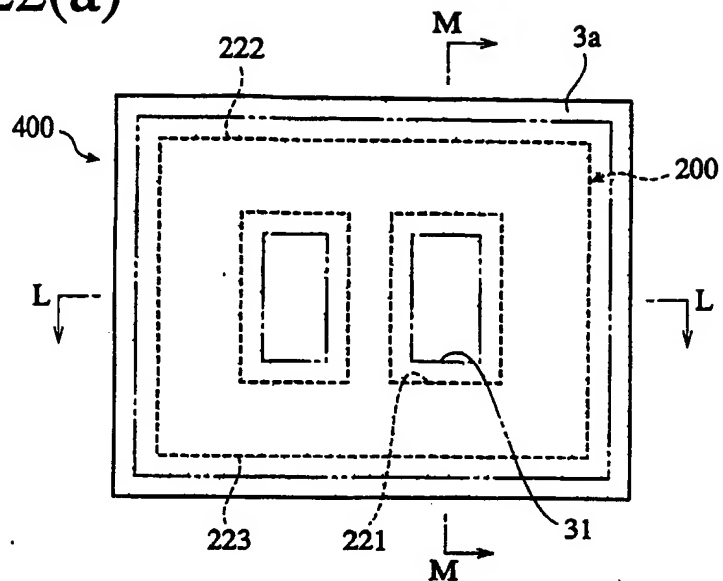


Fig. 22(b)

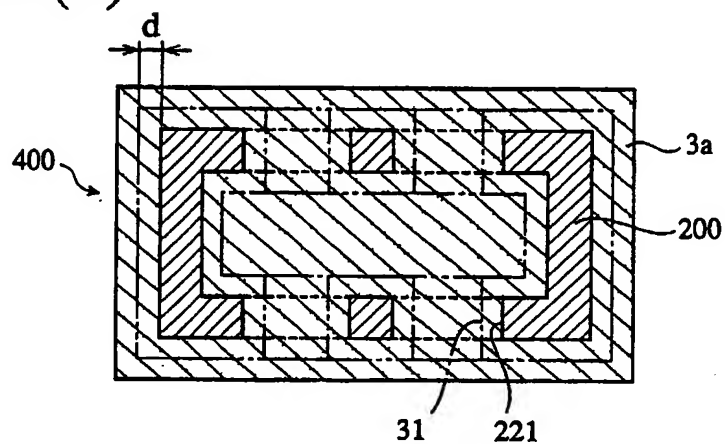


Fig. 22(c)

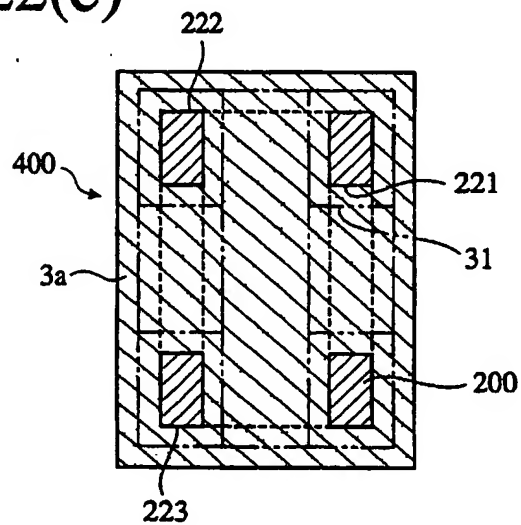


Fig. 23

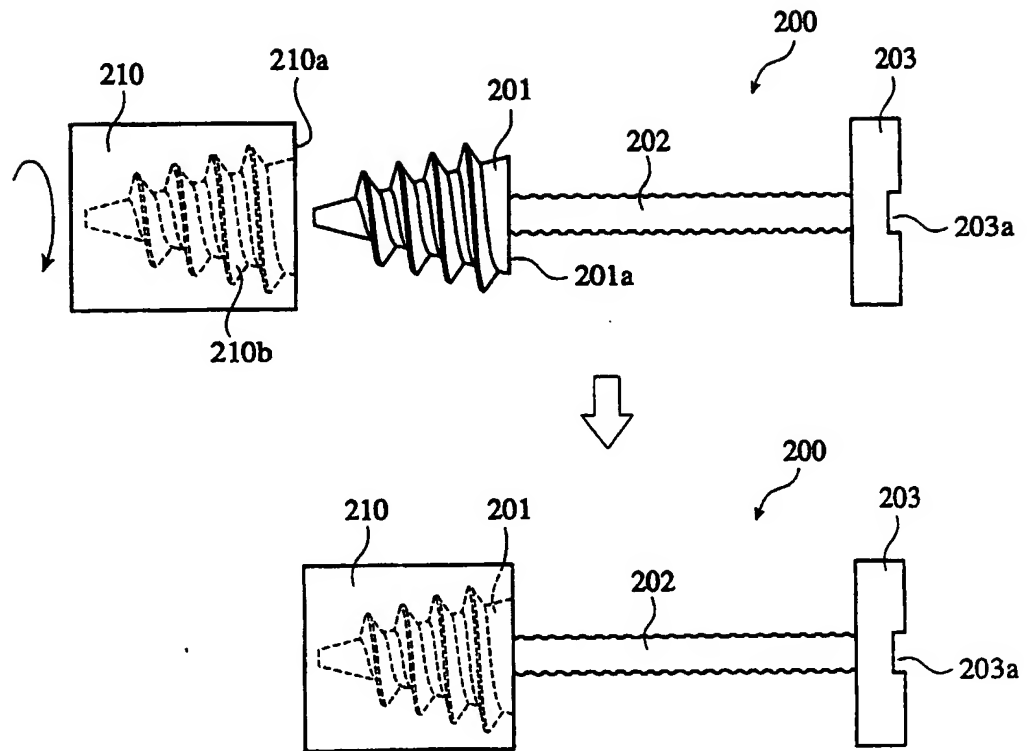


Fig. 24

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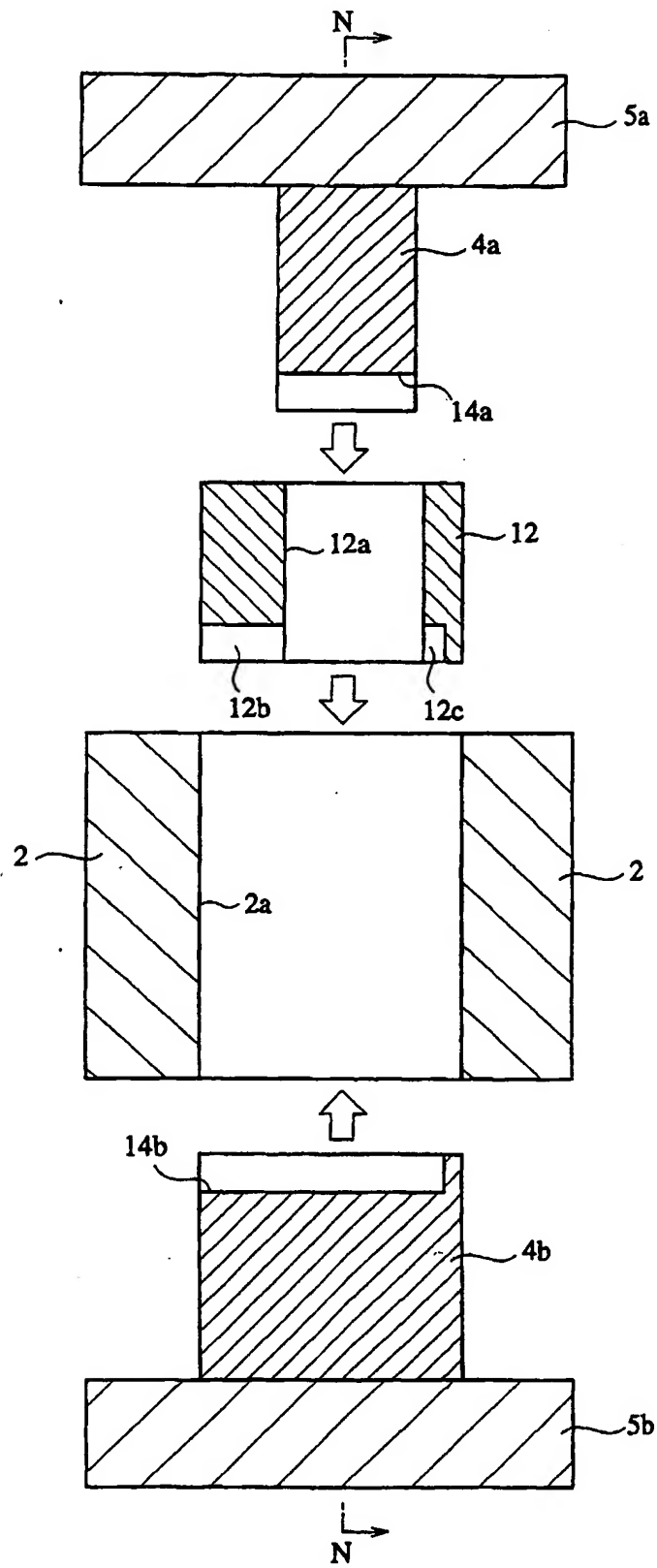


Fig. 25

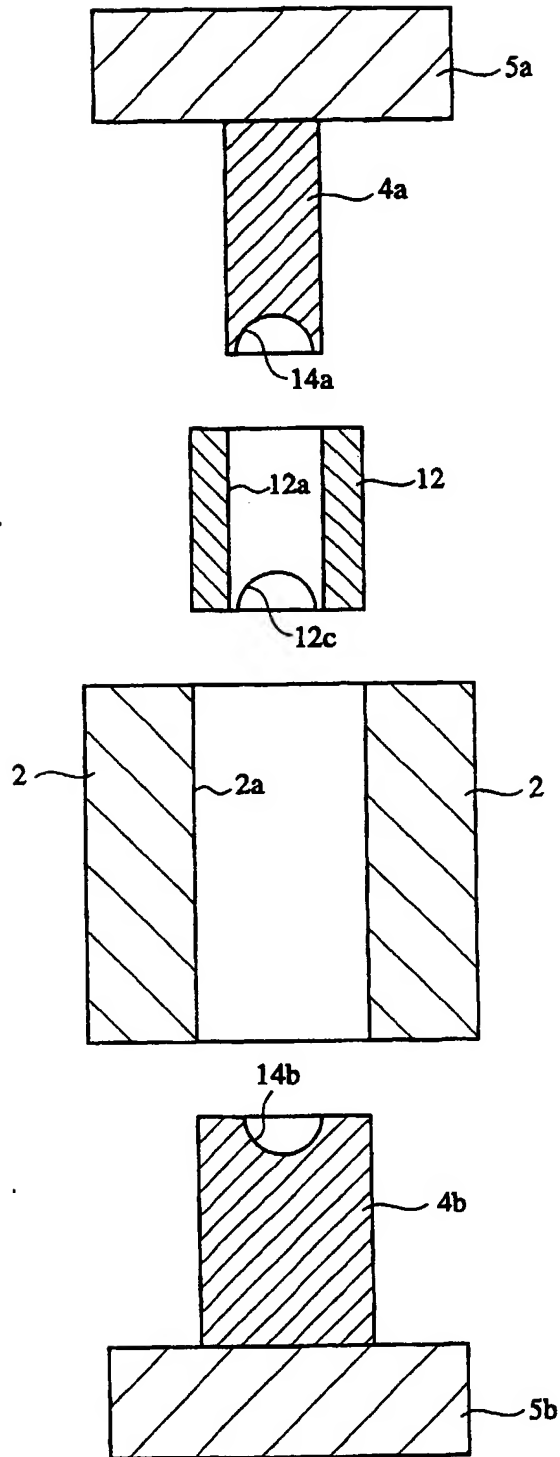


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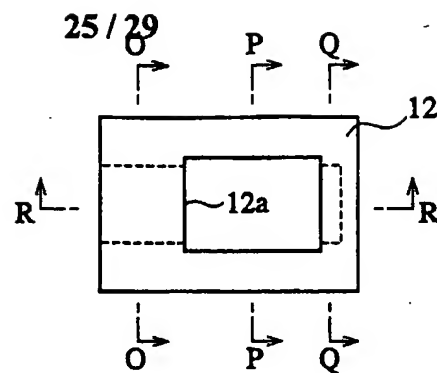


Fig. 26(b)

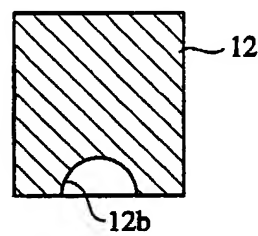


Fig. 26(c)

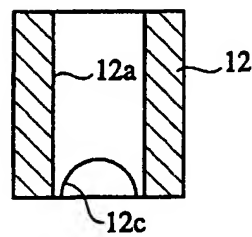


Fig. 26(d)

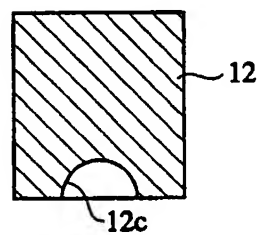


Fig. 26(e)

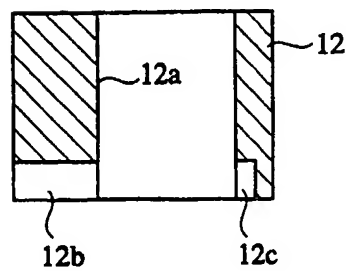


Fig. 27

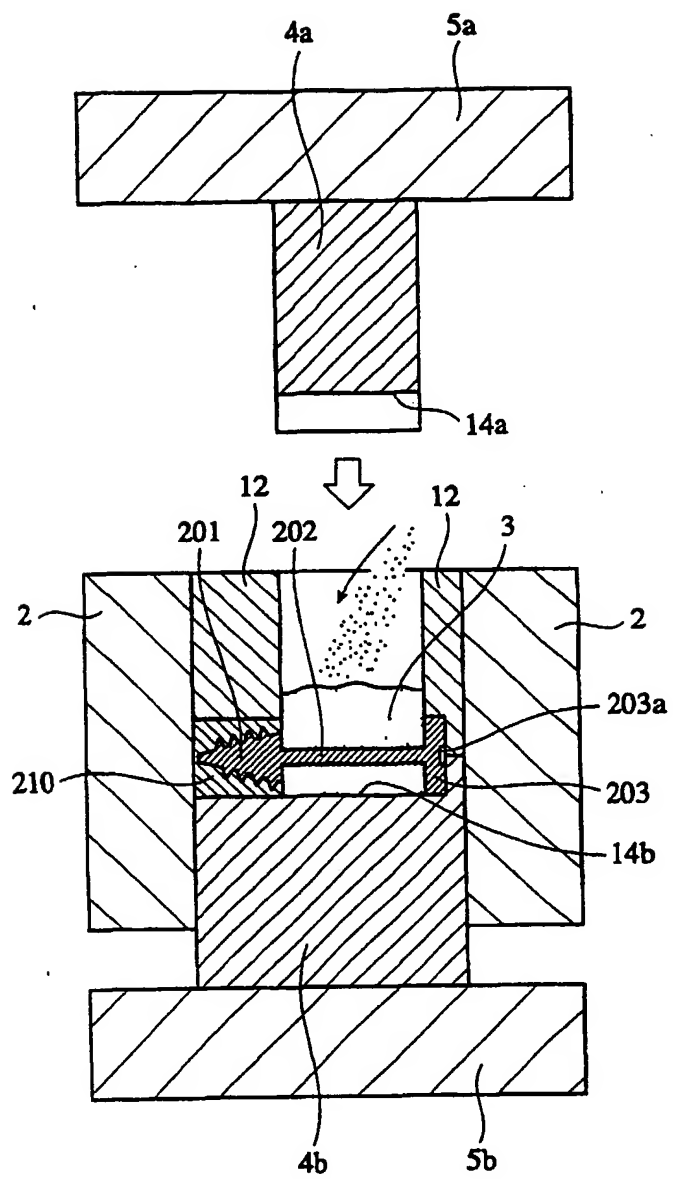


Fig. 28(a)

Fig. 29

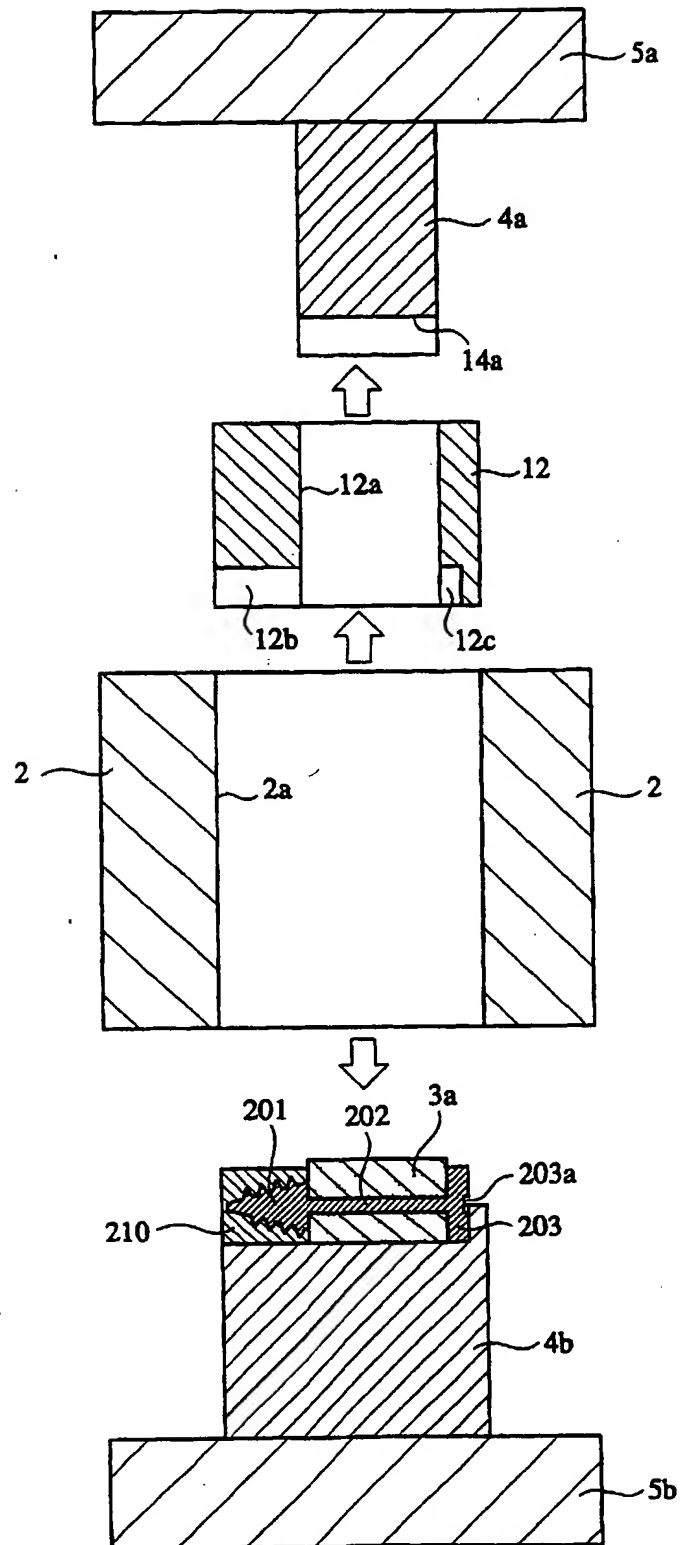


Fig. 30

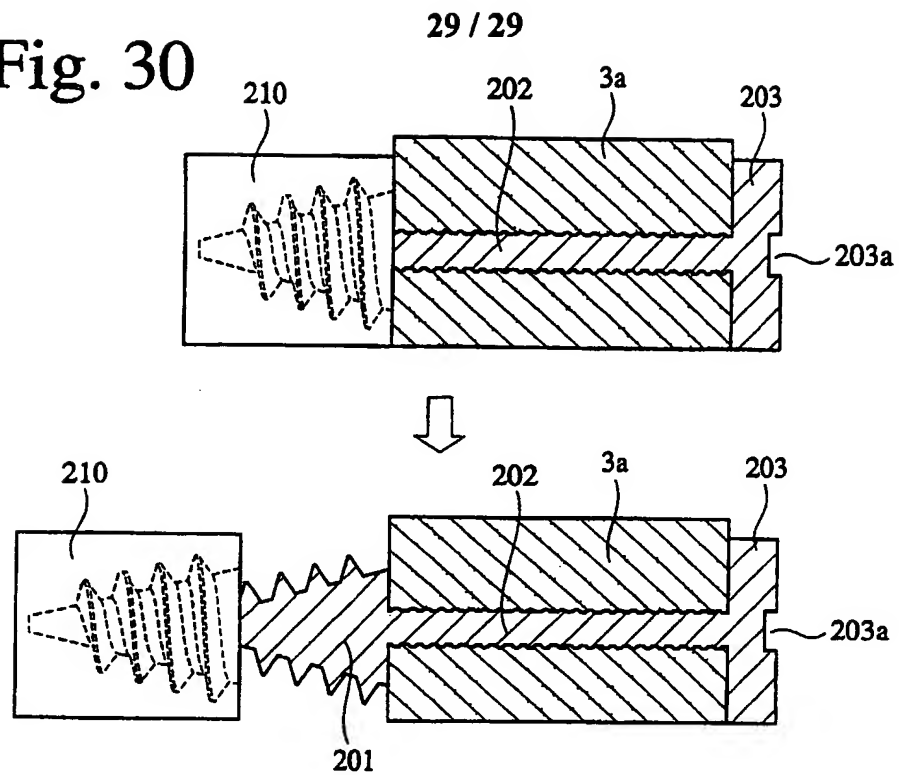
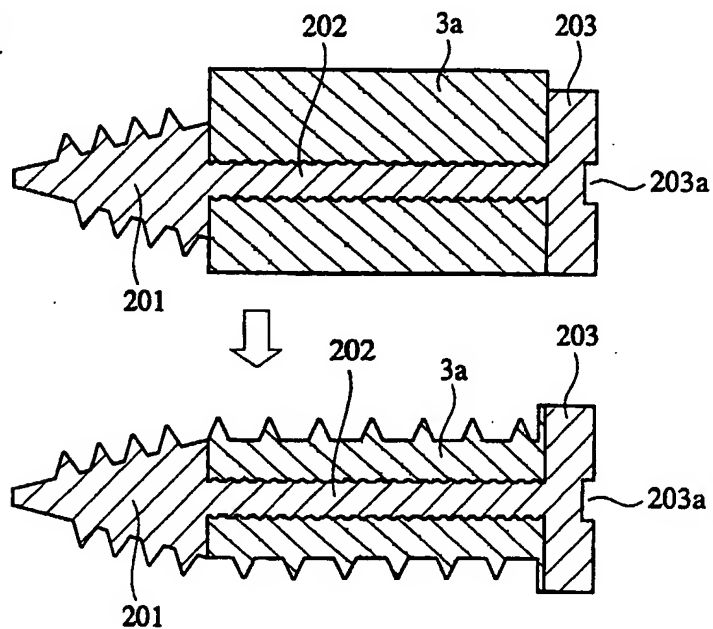


Fig. 31



CALCIUM PHOSPHATE-SYNTHETIC RESIN-METAL COMPOSITE BODY AND METHOD FOR  
PRODUCTION THEREOF

5       The present invention relates to a calcium phosphate-synthetic resin-metal composite body having excellent workability and biocompatibility and usable as artificial dental roots, bone reinforcements, etc., and a method for producing such a composite body.

Calcium phosphate is utilized for biomaterials such as artificial dental  
10 roots, bone reinforcements and dental cements because of excellent biocompatibility. However, it has poor toughness due to its nature as a ceramic and cannot be used for members requiring impact resistance. Thus, artificial dental roots and bone reinforcements are made of metallic materials which are not harmful to the human body, such as titanium and  
15 stainless steel. However, because calcium phosphate compounds, particularly hydroxyapatite, are much better in terms of biocompatibility, their use has been desired.

Under such circumstances, attempts have been made to combine calcium  
phosphate compounds with glass materials, metallic materials and synthetic  
20 resins, and some of the resultant composite bodies have been already put into practical use. However, when they are combined with glass materials, there are problems in that the glass elutes from the resultant composite bodies into the human body as over time, and that the composite bodies lack toughness.

25       Though attempts have been made to blend a molten synthetic resin and calcium phosphate particles to provide a composite body, the calcium phosphate particles easily collapse during blending, and the molten

synthetic resin easily covers the calcium phosphate particles in the course of molding the composite body. In addition, burring disadvantageously occurs during grinding.

A combination of a calcium phosphate-synthetic resin composite body with  
5 a calcium phosphate block is known to have improved biocompatibility. Though this composite body has excellent workability, biocompatibility and water resistance, it does not have excellent impact resistance because of the use of synthetic resin particles as reinforcements.

A composite material composed of a calcium phosphate compound and  
10 metallic materials is generally obtained by burying calcium phosphate compound particles in a metal frame, or by sintering a mixture of metal powder and calcium phosphate compound powder. In the former case, however, the calcium phosphate compound is likely to move from the metal frame in a living body. In the latter case, the calcium phosphate compound particles  
15 exposed on the surface of the composite, sintered body are easily detached.

Therefore, an object of the present invention is to seek provide a calcium phosphate-synthetic resin-metal composite body having excellent workability, biocompatibility and water resistance, as well as high impact resistance.

20 Another object of the present invention is to seek to provide a method for producing such a calcium phosphate-synthetic resin-metal composite body.

As a result of an intensive study in view of the above objects, the inventors have found that a composite body would be provided with further improved workability, biocompatibility, water resistance and impact  
25 resistance, if a metal member having excellent mechanical strength exists in a step of heat-pressing calcium phosphate particles (or calcium phosphate particles and a calcium phosphate block), synthetic resin particles I, which are at least partially cross-linked in advance, and uncross-linked, synthetic resin particles II. The present invention has been completed based on this

finding.

Thus, the calcium phosphate-synthetic resin-metal composite body of the present invention is produced by pressing a metal member, calcium phosphate particles (or calcium phosphate particles and a calcium phosphate block),  
5 synthetic resin particles I, which are at least partially cross-linked in advance, and uncross-linked, synthetic resin particles II while heating, the calcium phosphate particles (or the calcium phosphate particles and the calcium phosphate block) being exposed on at least part of the surface of the composite body.

10 In the calcium phosphate-synthetic resin-metal composite body of the present invention, the synthetic resin particles I are softened while retaining their shapes to some extent, whereas the uncross-linked, synthetic resin particles II having thermoplasticity are softened or melted during pressing while heating. When the composite body contains a porous calcium  
15 phosphate block, the softened or molten synthetic resin particles preferably enter into pores of the calcium phosphate block. The metal member and calcium phosphate particles (or calcium phosphate particles and a calcium phosphate block) are firmly fixed in the composite body by bonding the synthetic resin particles to the metal member and the calcium phosphate  
20 particles (or the calcium phosphate particles and the calcium phosphate block).

In the calcium phosphate-synthetic resin-metal composite body, it is preferable that the synthetic resin particles I, which are at least partially cross-linked in advance, and the uncross-linked, synthetic resin particles  
25 II are bonded to each other. By pressing while heating, the synthetic resin particles I are softened while retaining their shapes to some extent for bonding, and the synthetic resin particles II are softened or melted to enter voids between the particles to form a calcium phosphate-synthetic resin composite body. The synthetic resin particles II filling voids between the

particles act as binders.

In a normal condition, not only are the calcium phosphate particles firmly fixed by the synthetic resin particles I and II, but also the synthetic resin particles I and II are firmly bonded to each other. At the  
5 time of grinding and polishing, however, exfoliation occurs at interfaces between the calcium phosphate particles and the synthetic resin particles and at interfaces between the synthetic resin particles I and II. Therefore, the calcium phosphate-synthetic resin-metal composite body of the present invention has excellent workability.

10 A calcium phosphate-synthetic resin composite layer preferably covers the entire surface of the metal member. Particularly excellent in biocompatibility is the calcium phosphate-synthetic resin-metal composite body comprising a composite layer covering the entire surface of the metal member such that the metal member is not exposed.

15 The metal member is preferably made of a metal or an alloy selected from the group consisting of pure titanium, titanium alloys and stainless steel. At least part of the metal member preferably has a thickness of 0.5 mm or more. An example of preferable shapes of the metal member is a screw shape. In this case, a composite layer composed of calcium phosphate particles and  
20 synthetic resin particles I and II is preferably formed on a trunk of a screw.

The metal member is preferably in the form of a mesh. In this case, each side of the metal mesh is preferably covered with the calcium phosphate-synthetic resin composite layer. When the metal member is in the form of a  
25 mesh, the calcium phosphate-synthetic resin composite layer easily adheres to the metal member.

A further example of preferable shapes of the metal member is a hollow shape. In this case, the entire surface of the metal member is preferably covered with a hollow calcium phosphate-synthetic resin composite layer.

When the hollow composite body is implanted in a living body, a bone material may be charged into the composite body. It is preferable that the metal member has a window, and that the calcium phosphate-synthetic resin-metal composite body has an opening in alignment with the window.

5       The calcium phosphate particles are preferably porous in terms of biocompatibility. The average particle size of the calcium phosphate particles is preferably 0.001 to 10 mm, and the calcium/phosphorus molar ratio is preferably 1.4 to 2.0. The calcium phosphate particles are preferably sintered in advance.

10       Both of the synthetic resin particles I and II are preferably made of a water-insoluble acrylic or polystyrene resin, particularly polymethyl methacrylate. The content of the uncross-linked, synthetic resin particles II is preferably 0.2 to 50% by mass based on the total amount of the synthetic resin particles I and II.

15       The mass ratio of the calcium phosphate particles to the synthetic resin particles in the calcium phosphate-synthetic resin-metal composite body is preferably 1/9 to 8/2.

When the calcium phosphate-synthetic resin-metal composite body comprises a calcium phosphate block, the calcium phosphate block is  
20 preferably porous in terms of biocompatibility. A calcium/phosphorus molar ratio in the calcium phosphate block is preferably 1.4 to 2.0. Also, preferably used from a practical standpoint is the sintered calcium phosphate block having a thickness of at least 1 mm.

The method for producing the calcium phosphate-synthetic resin-metal  
25 composite body of the present invention comprises the steps of (a) introducing a metal member, the calcium phosphate particles (or calcium phosphate particles and a calcium phosphate block), and synthetic resin particles I and II into a cavity of a molding die, such that the synthetic resin particles surround the calcium phosphate particles, and such that the

calcium phosphate particles and/or the calcium phosphate block are present on at least part of a surface of the composite body; and (b) pressing them in a cavity of a molding die while heating, so that the synthetic resin particles are bonded to the metal member and the calcium phosphate particles  
5 (or calcium phosphate particles and a calcium phosphate block).

The calcium phosphate particles (and/or the calcium phosphate block) are preferably sintered. Its sintering temperature is preferably 500°C to 1,300°C.

The step of pressing while heating is preferably carried out in vacuum  
10 or in an atmosphere containing no oxygen.

The method for producing the calcium phosphate-synthetic resin-metal composite body according to a preferable embodiment of the present invention comprises using a hollow metal member; pressing a mixture of the calcium phosphate particles and the synthetic resin particles I and II surrounding  
15 the metal member while heating to provide a composite body comprising the metal member embedded in a calcium phosphate-synthetic resin composite body; and grinding part of the calcium phosphate-synthetic resin composite body in the metal member-embedded composite body to provide a hollow calcium phosphate-synthetic resin-metal composite body.

20 In a preferable example of the above-described method, a hollow metal member having a window is used, and the calcium phosphate-synthetic resin composite body is partially cut by machining at a position aligned with the window to form a hollow calcium phosphate-synthetic resin-metal composite body having a window.

25 The method for producing a screw-shaped, calcium phosphate-synthetic resin-metal composite body according to another preferable embodiment of the present invention comprises using screw-shaped metal member; placing the metal member in a cavity of a molding die with a cap put on its thread; charging a mixture of the calcium phosphate particles and the synthetic resin

particles I and II into the molding die cavity; pressing them while heating to form a calcium phosphate-synthetic resin composite body around the metal member; removing the cap from the thread of the screw; and threading the calcium phosphate-synthetic resin composite body around a trunk of the screw-  
5 shaped metal member.

Preferably used in the above method is a molding die comprising a stationary die member having a cavity extending in its entire length in a vertical direction; a lower punch having a cavity having a shape for receiving the capped, screw-shaped metal member and entering into the cavity  
10 of the stationary die member from its lower end; a protection die having a cavity extending in its entire length in a vertical direction and a cavity having a shape for receiving the capped, screw-shaped metal member, which abuts the lower punch; and a vertically movable upper punch having a cavity having the same shape as that of the cavity of the lower punch at a position  
15 aligned with the cavity of the lower punch, which enters into the vertical cavity of the protection die from above to abut the lower punch.

In a preferred embodiment, the capped, screw-shaped metal member is placed in the cavity of the lower punch; the lower punch is positioned in the cavity of the stationary die member; the protection die is caused to move  
20 downward so that the cavity of the protection die abuts the cavity of the lower punch; a mixture of the calcium phosphate particles and the synthetic resin particles I and II is charged into the combined cavities of the lower punch and the protection die; the upper punch is caused to move downward to press the mixture while heating, thereby forming the calcium phosphate-  
25 synthetic resin composite body around the trunk of the metal member.

Embodiments of the present invention will now be described in detail with reference to the accompanying drawings, in which:-

Fig. 1(a) is a top view showing one example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

Fig. 1(b) is a side view showing the example shown in Fig. 1(a);

Fig. 2(a) is a top view showing another example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

Fig. 2(b) is a vertical, cross-sectional view taken along the line A-A in Fig. 2(a);

Fig. 3(a) is a top view showing a further example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

Fig. 3(b) is a vertical, cross-sectional view taken along the line B-B in Fig. 3(a);

Fig. 4(a) is a top view showing a still further example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

Fig. 4(b) is a vertical, cross-sectional view taken along the line C-C in Fig. 4(a);

Fig. 5(a) is a top view showing a still further example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

Fig. 5(b) is a vertical, cross-sectional view taken along the line D-D in Fig. 5(a);

Fig. 6(a) is a top view showing a still further example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

Fig. 6(b) is a vertical, cross-sectional view taken along the line E-E in Fig. 6(a);

Fig. 7(a) is a top view showing a still further example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

Fig. 7(b) is a vertical, cross-sectional view taken along the line F-F in Fig. 7(a);

Fig. 8(a) is a top view showing a still further example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

Fig. 8(b) is a vertical, cross-sectional view taken along the line G-G in Fig. 8(a);

Fig. 9(a) is a top view showing a still further example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

5 Fig. 9(b) is a vertical, cross-sectional view taken along the line H-H in Fig. 9(a);

Fig. 10(a) is a perspective view showing a still further example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

10 Fig. 10(b) is an enlarged cross-sectional view showing part of the example shown in Fig. 10(a);

Fig. 11(a) is a perspective view showing a still further example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

15 Fig. 11(b) is an enlarged cross-sectional view showing part of the example shown in Fig. 11(a);

Fig. 12 is a perspective view showing one example of a metal member;

Fig. 13 is a perspective view showing a calcium phosphate-synthetic resin-metal composite body comprising the metal member shown in Fig. 12;

20 Fig. 14(a) is a side view showing the calcium phosphate-synthetic resin-metal composite body shown in Fig. 13;

Fig. 14(b) is a cross-sectional view taken along the line J-J in Fig. 14(a);

Fig. 14(c) is a cross-sectional view taken along the line K-K in Fig. 25 14(a);

Fig. 15(a) is a side view showing a still further example of a calcium phosphate-synthetic resin-metal composite body of the present invention;

Fig. 15(b) is a cross-sectional view showing the example shown in Fig. 15(a);

Fig. 16 is a schematic view showing the structure of vacuum pressing/heating apparatus;

Fig. 17 is an exploded cross-sectional view showing the molding die of the vacuum pressing/heating apparatus shown in Fig. 16;

5     Fig. 18 is a vertical cross-sectional view showing a state in which a metal member, a mixture and a calcium phosphate block are charged into a cavity of the molding die shown in Fig. 17;

Fig. 19(a) is a cross-sectional view showing the step of producing a plate-shaped calcium phosphate-synthetic resin-metal composite body, in  
10 which a cylindrical metal member and a mixture are charged into a cavity of the molding die of the vacuum pressing/heating apparatus;

Fig. 19(b) is a cross-sectional view showing the step of producing a plate-shaped calcium phosphate-synthetic resin-metal composite body, in which the metal member and the mixture charged into the molding die cavity  
15 are heated while pressing;

Fig. 20(a) is a cross-sectional view showing the step of producing a metal member-embedded composite body, in which a cylindrical metal member and a mixture are charged into a cavity of the molding die of the vacuum pressing/heating apparatus;

20     Fig. 20(b) is a cross-sectional view showing the step of producing a metal member-embedded composite body, in which the metal member and the mixture charged into the molding die cavity are heated while pressing;

Fig. 21 is a perspective view showing the cylindrical metal member-embedded composite body obtained by the process shown in Fig. 20;

25     Fig. 22(a) is a side view showing the cylindrical metal member-embedded composite body shown in Fig. 21;

Fig. 22(b) is a cross-sectional view taken along the line L-L in Fig. 22(a);

Fig. 22(c) is a cross-sectional view taken along the line M-M in Fig.

22(a)

Fig. 23 is a cross-sectional view showing the step for putting a cap on a metal screw to produce the composite body shown in Fig. 15;

Fig. 24 is a vertical cross-sectional view showing the molding die of  
5 the vacuum pressing/heating apparatus for producing the screw-shaped composite body shown in Fig. 15;

Fig. 25 is a cross-sectional view taken along the line N-N in Fig. 24;

Fig. 26(a) is a top view showing a protection die used in the vacuum pressing/heating apparatus shown in Fig. 24;

10 Fig. 26(b) is a cross-sectional view taken along the line O-O in Fig. 26(a);

Fig. 26(c) is a cross-sectional view taken along the line P-P in Fig. 26(a);

Fig. 26(d)' is a cross-sectional view taken along the line Q-Q in Fig. 15 26(a);

Fig. 26(e) is a cross-sectional view taken along the line R-R in Fig. 26(a);

Fig. 27 is a vertical cross-sectional view showing a state in which the mixture is charged into the molding die of the vacuum pressing/heating  
20 apparatus with the capped screw placed therein;

Fig. 28(a) is a vertical cross-sectional view showing a state in which the mixture is heated while pressing with the capped screw fixed in the molding die;

Fig. 28(b) is a cross-sectional view taken along the line S-S in Fig. 25 28(a);

Fig. 29 is a vertical cross-sectional view showing a state in which the molding is taken out from the molding die after pressing and heating;

Fig. 30 is a cross-sectional view showing the removal of the cap from the molded product; and

Fig. 31 is a cross-sectional view showing the threading of the cap-detached molded product.

[1] Calcium phosphate-synthetic resin-metal composite body.

The calcium phosphate-synthetic resin-metal composite body comprises 5 calcium phosphate particles (or calcium phosphate particles and a calcium phosphate block), synthetic resin particles I, which are at least partially cross-linked in advance, and uncross-linked, synthetic resin particles II.

(1) Metal member

The metal member is not limited as long as it has sufficient strength 10 to function as reinforcement in the composite body and it is not harmful to the human body, and may be made of generally used materials. The metal member is preferably at least one metal or alloy selected from the group consisting of pure titanium, titanium alloys and stainless steel.

The metal member is preferably shaped as a column, cylinder, screw, 15 mesh or plate. The outer diameter of the columnar metal member is preferably the same as or about 1 to 5 mm smaller than that of the calcium phosphate-synthetic resin-metal composite body. Though not particularly limited as long as the metal member is shorter than the calcium phosphate-synthetic resin-metal composite body, the height of the metal member is preferably 20 about 0.5 mm to 100 mm. When a screw-shaped metal member is used, the outer diameter of the trunk of the screw is preferably 1 to 10 mm. When a cylindrical metal member is used, the thickness of the metal member is preferably 0.5 mm to 20 mm. When the thickness of the metal member is less than 0.5 mm, the metal member may not be strong enough to function as 25 reinforcement in the composite body. On the other hand, when the thickness of the metal member exceeds 20 mm, the composite body may have low workability and biocompatibility.

The metal mesh is preferably constituted by wires having a diameter of 3 mm or less. The number of mesh openings is not particularly limited;

the mesh openings may be small or large. To have improved adhesion to synthetic resins, the surface of the metal member may be subjected to an anchoring treatment, etc. before heat-pressing.

In the case of a plate-shaped metal member, it preferably has a thickness of about 0.5 to 5 mm. The metal member is preferably provided with a plurality of through-holes perpendicular to its plane. Where the plate-shape metal member is completely covered with the calcium phosphate-synthetic resin composite body, the calcium phosphate-synthetic resin composite layers on both sides of the metal member can be connected with each other via the through-holes. The through-holes are preferably arranged at an equal interval. The percentage of the through-holes to the metal member in area is preferably 5 to 90%. When the total area of the through-holes is less than 5%, the contact area of the calcium phosphate-synthetic resin composite layers may be too small, resulting in easy peeling from the metal member. On the other hand, when it exceeds 90%, the metal member may not have enough strength as reinforcement.

The metal member preferably (a) is hollow, (b) has an upper end and a lower end, at least one of which is open, and (c) has one or more windows, i.e. it has the shape of a cylinder having a circular, oval or rectangular cross section. Fig. 12 shows one specific example of such a metal member. This metal member 200 is a cylinder having a rectangular cross section having a pair of windows 221 in each sidewall. The cylindrical, windowed metal member can provide a cylindrical, windowed calcium phosphate-synthetic resin-metal composite body. When the cylindrical, windowed calcium phosphate-synthetic resin-metal composite body is implanted in a living body, osteoblasts and body fluids easily enter into its hollow portion, so that the bone is easily regenerated around the composite body.

Though not particularly restrictive, the number of windows in the metal member is typically 5 or less, preferably 4 or less, in each surface

in the case of the cylindrical calcium phosphate-synthetic resin-metal composite body having a rectangular cross section. The total area of the windows 221 is preferably 80% or less of the area of each sidewall. When the total area of the windows 221 is more than 80%, the metal member may not have  
5 enough strength as reinforcement for the composite body.

(2) Calcium phosphate particles

The calcium/phosphorus molar ratio in the calcium phosphate particles is preferably 1.4 to 2.0. Specific examples of the calcium phosphate particles include apatites such as hydroxyapatite and fluoroapatite, calcium  
10 phosphates such as tricalcium phosphate and tetracalcium phosphate, and mixtures thereof.

The calcium phosphate particles may be porous or dense, but porous particles are more preferable. In the case of porous calcium phosphate particles, their porosity is preferably 20 to 70%. Though the pores of the  
15 porous particles may be of various sizes, they preferably have diameters of 10 to 2000  $\mu\text{m}$ .

It is preferable that the calcium phosphate particles have particle sizes so that their average particle diameter is 0.001 to 10 mm. The more preferable average particle diameter of the calcium phosphate particles is  
20 0.01 to 6 mm. When the average particle diameter of the calcium phosphate particles is more than 10 mm, the calcium phosphate particles may be easily detached from the calcium phosphate-synthetic resin-metal composite body during use. On the other hand, when it is less than 0.001 mm, they may easily agglomerate with poor dispersibility and high cost.

25 The calcium phosphate particles are preferably sintered before pressing while heating. The sintering temperature is preferably 500 to 1300°C and more preferably 700 to 1200°C. When the sintering temperature is below 500°C, the calcium phosphate particles may easily collapse. Particularly in the case of the porous calcium phosphate particles, they may

deform and lose their porosity due to the crushing of pores by the application of pressure. When the sintering temperature is above 1300°C, the calcium phosphate compound may undesirably decompose or deteriorate.

The sintering time, for which the above sintering temperature is kept, is preferably 1 to 10 hours. When the sintering time is less than 1 hour, the calcium phosphate particles may not exhibit a sufficient reinforcing effect even if sintered. On the other hand, even when the sintering time is more than 10 hours, no further effect may be obtained, only resulting in increased cost. The more preferable sintering time is 2 to 10 hours. Though not particularly limited, the sintering atmosphere is preferably air to prevent decomposition of the calcium phosphate particles.

(3) Synthetic resin particles

The synthetic resin particles comprise synthetic resin particles I, which are at least partially cross-linked in advance, and uncross-linked, synthetic resin particles II. The synthetic resin particles I, which are at least partially cross-linked in advance, and the uncross-linked, synthetic resin particles II are not limited as long as they are not harmful to the human body, and materials known in the art can be used therefor. The synthetic resin particles I and II preferably comprise a water-insoluble acrylic or polystyrene resin and the like, particularly polymethyl methacrylate. The same or different materials may be used for the synthetic resin particles I and II.

Each of the synthetic resin particles I and II preferably has an average particle diameter of 0.05 to 500  $\mu\text{m}$ , more preferably 0.1 to 100  $\mu\text{m}$ . Also, the average particle diameters of the synthetic resin particles are preferably smaller than those of the calcium phosphate particles.

The content of the synthetic resin particles II is preferably 0.2 to 50% by mass based on the total amount of the synthetic resin particles I and II. When the content of the synthetic resin particles II is less than 0.2%,

the composite body may not be sufficiently stable in water. On the other hand, when their content is more than 50% by mass, not only are the synthetic resin particles more likely to intrude into the porous calcium phosphate particles at the step of pressing while heating, but also the resultant composite body may have low workability.

(4) Calcium phosphate block

The calcium phosphate-synthetic resin-metal composite body of the present invention may or may not contain a calcium phosphate block. When containing a calcium phosphate block, its composition is preferably the same as that of the calcium phosphate particles.

The calcium phosphate block may be porous or dense, though a porous block is more preferable. In the case of a porous calcium phosphate block, its porosity is preferably 5 to 90%. Though the pores of the calcium phosphate block may be of various sizes, they preferably have diameters of 20 to 2000  $\mu\text{m}$ .

Though not particularly limited, the calcium phosphate block may be in the shape of a rectangular column or a circular column. Though not particularly limited as long as the calcium phosphate block is thinner than the calcium phosphate-synthetic resin-metal composite body, the thickness of the calcium phosphate block is preferably 1 mm or more from a practical standpoint.

(5) Structure of calcium phosphate-synthetic resin-metal composite body

In the calcium phosphate-synthetic resin-metal composite body of the present invention, the calcium phosphate particles (or the calcium phosphate particles and the calcium phosphate block) are exposed on at least part of surface thereof.

Figs. 1 to 11 and Figs. 13 to 15 show calcium phosphate-synthetic resin-metal composite bodies of various embodiments of the present invention, without limiting the present invention thereto. Though not particularly

limited, the calcium phosphate-synthetic resin-metal composite body may be in the shape of a rectangular column, a circular column, plate cylinder, screw or a combination thereof. Figs. 1 to 9 show examples of calcium phosphate-synthetic resin-metal composite bodies having a circular column shape. Figs. 10 and 11 show examples of calcium phosphate-synthetic resin-metal composite bodies having a plate shape. Figs. 13 and 14 show examples of calcium phosphate-synthetic resin-metal composite bodies having a cylinder shape. Fig. 15 shows an example of calcium phosphate-synthetic resin-metal composite body having a screw shape.

10 Figs. 1 to 6 show examples of calcium phosphate-synthetic resin-metal composite bodies each comprising a calcium phosphate block. Figs. 7 to 11 and Figs. 13 to 15 show examples of calcium phosphate-synthetic resin-metal composite bodies each comprising no calcium phosphate block.

Fig. 1(a) is a top view showing a calcium phosphate-synthetic resin-metal composite body, and Fig. 1(b) is a side view thereof. The calcium phosphate-synthetic resin-metal composite body shown in Figs. 1(a) and 1(b) has a triple-layer structure comprising an upper layer constituted by a calcium phosphate block 300, a middle layer (a calcium phosphate-synthetic resin composite layer 3a) composed of a mixture of calcium phosphate particles 100 and synthetic resin particles, and a lower layer constituted by the metal member 200 adhering to the middle layer. The synthetic resin particles in the calcium phosphate-synthetic resin composite layer 3a are composed of synthetic resin particles I, which are at least partially cross-linked in advance, and uncross-linked, synthetic resin particles II. The cross-linked, synthetic resin particles I and the uncross-linked, synthetic resin particles II surround and tightly fix the calcium phosphate particles 100. The calcium phosphate particles 100 are exposed on the surface of the calcium phosphate-synthetic resin composite layer 3a.

In each of Figs. 2 to 9, (a) is a top view showing a calcium

phosphate-synthetic resin-metal composite body, and (b) is a vertical, cross-sectional view thereof. The calcium phosphate-synthetic resin-metal composite body shown in Figs. 2(a) and 2(b) has a triple-layer structure comprising a cylindrical calcium phosphate block 300, a calcium phosphate-synthetic resin composite layer 3a contained therein, and a cylindrical metal member 200 contained in the calcium phosphate-synthetic resin composite layer 3a. The composition of the calcium phosphate-synthetic resin composite layer 3a may be the same as in the example shown in Fig. 1.

Figs. 3 to 5 show examples of calcium phosphate-synthetic resin-metal composite bodies each comprising a cylindrical metal member 200 covering a lateral surface thereof. The calcium phosphate-synthetic resin-metal composite body shown in Figs. 3(a) and 3(b) has a structure comprising an outer layer constituted by a metal member 200, a calcium phosphate-synthetic resin composite layer 3a contained therein and two calcium phosphate blocks 300 exposed centrally on upper and lower surfaces of the composite body of the calcium phosphate-synthetic resin composite layer 3a. The composition of the calcium phosphate-synthetic resin composite layer 3a may be the same as in the example shown in Fig. 1.

The calcium phosphate-synthetic resin-metal composite body shown in Figs. 4(a) and 4(b) has a structure comprising a metal member 200 having a central horizontal partition, two circular columnar calcium phosphate blocks 300 arranged on either side of the partition, and calcium phosphate-synthetic resin composite layers 3a charged between the partition of the metal member 200 and the calcium phosphate blocks 300, 300. In other portions, this composite body may be the same as that shown in Fig. 3.

The calcium phosphate-synthetic resin-metal composite body shown in Figs. 5(a) and 5(b) has a structure comprising an outer layer constituted by a metal member 200, and an inner layer constituted by a calcium phosphate-synthetic resin composite layer 3a composed of a mixture of the calcium

phosphate particles 100 and the synthetic resin particles and a pair of calcium phosphate blocks 300, 300 sandwiching the composite layer 3a. The composition of the calcium phosphate-synthetic resin composite layer 3a may be the same as in the example shown in Fig. 1.

5       The calcium phosphate-synthetic resin-metal composite body shown in Figs. 6(a) and 6(b) has a structure comprising a cylindrical calcium phosphate block 300 (outer layer), a calcium phosphate-synthetic resin composite layer 3a (middle layer) contained in the calcium phosphate block 300, and a circular metal column 200 (inner layer) contained in the calcium  
10 phosphate-synthetic resin composite layer 3a. The calcium phosphate-synthetic resin composite layer 3a encloses the columnar metal member 200. The composition of the calcium phosphate-synthetic resin composite layer 3a may be the same as in the example shown in Fig. 1.

      The calcium phosphate-synthetic resin-metal composite body shown in  
15 Figs. 7(a) and 7(b) has a double-layer structure comprising a calcium phosphate-synthetic resin composite layer 3a and a layer constituted by a metal member 200 adhering to a lower surface of the calcium phosphate-synthetic resin composite layer 3a. The composition of the calcium phosphate-synthetic resin composite layer 3a may be the same as in the  
20 example shown in Fig. 1.

      The calcium phosphate-synthetic resin-metal composite body shown in Figs. 8(a) and 8(b) has a double-layer structure comprising a cylindrical calcium phosphate-synthetic resin composite layer 3a (outer layer) and a columnar metal member 200 (inner layer) adhering to an inside surface of the  
25 cylindrical calcium phosphate-synthetic resin composite layer 3a. The composition of the calcium phosphate-synthetic resin composite layer 3a may be the same as in the example shown in Fig. 1.

      The calcium phosphate-synthetic resin-metal composite body shown in Fig. 9(a) and 9(b) has a double-layer structure comprising an outer layer

constituted by a cylindrical metal member 200 and an inner layer constituted by a calcium phosphate-synthetic resin composite layer 3a adhering to the metal member 200. The composition of the calcium phosphate-synthetic resin composite layer 3a may be the same as in the example shown in Fig. 1.

5       The calcium phosphate-synthetic resin-metal composite body shown in Figs. 10(a) and 10(b) has a plate shape, and comprises a mesh-shaped metal member 200, and a calcium phosphate-synthetic resin composite layer 3a covering the entire surface of the metal member 200. The composition of the calcium phosphate-synthetic resin composite layer 3a may be the same as in  
10 the example shown in Fig. 1.

      The calcium phosphate-synthetic resin-metal composite body shown in Figs. 11(a) and 11(b) comprises a plate-shaped metal member 200 and a calcium phosphate-synthetic resin composite layer 3a covering the entire surface of the metal member 200. The metal member 200 has a plurality of through-holes  
15 230 arranged at a constant interval. As shown in Fig. 11(b), the calcium phosphate-synthetic resin composite layer 3a fills the through-holes 230, so that the calcium phosphate-synthetic resin composite layers 3a on both sides of the metal member 200 are connected with each other. Thus, the calcium phosphate-synthetic resin composite layer 3a does not easily peel off from  
20 the metal member 200. The composition of the calcium phosphate-synthetic resin composite layer 3a may be the same as in the example shown in Fig. 1.

      Figs. 13 and 14 show another example of the calcium phosphate-synthetic resin-metal composite body. This composite body has a cylindrical shape with a rectangular cross section, which is constituted by the metal  
25 member 200 shown in Fig. 12 and a calcium phosphate-synthetic resin composite layer 3a entirely covering the metal member 200.

      Fig. 14(a) is a side view showing the calcium phosphate-synthetic resin-metal composite body of Fig. 13, Fig. 14(b) is a cross-sectional view taken along the line J-J in Fig. 14(a), and Fig. 14(c) is a cross-sectional

view taken along the line K-K in Fig. 14(a). This calcium phosphate-synthetic resin-metal composite body has openings 31 in alignment with the windows 221 of the metal member 200. As shown in Fig. 14(b), the inside and outside surfaces of the metal member 200 and the side surfaces of the windows 5 221 are covered with the calcium phosphate-synthetic resin composite layer 3a. As shown in Fig. 14(c), because the upper surface 222 and the lower surface 223 of the metal member 200 are also covered with the calcium phosphate-synthetic resin composite layer 3a, the metal member 200 is not exposed at all. In other words, the cylindrical, windowed metal member 200 10 is completely embedded in the calcium phosphate-synthetic resin composite layer 3a.

Fig. 15(a) shows a side view of a screw-shaped composite body, and Fig. 15(b) shows a vertical cross-section thereof. This screw-shaped, calcium phosphate-synthetic resin-metal composite body comprises a metal 15 screw 200 comprising a thread 201 having a substantially conical shape, a trunk 202 having a smaller outer diameter than a base diameter of the conical thread 201, and a head 203 having a larger outer diameter than the base diameter of the conical thread 201; and a calcium phosphate-synthetic resin composite layer 3a covering the trunk 202. Each of the thread 201 and the 20 calcium phosphate-synthetic resin composite layer 3a has a threaded surface. The trunk 202 preferably has an irregular surface to increase adhesion to the synthetic resin particles I and II. The screw head 203 has a plus- or minus-shaped groove 203a to rotate the screw-shaped composite body 200. As in the example shown in Fig. 1, the calcium phosphate-synthetic resin composite 25 layer 3a is composed of a uniform mixture of the calcium phosphate particles 100 and the synthetic resin particles I and II. The calcium phosphate particles 100 are exposed on the surface of the calcium phosphate-synthetic resin composite layer 3a.

[2] Production of a calcium phosphate-synthetic resin-metal composite

body

(1) First embodiment

The present invention utilizes a pressing/heating method to produce the calcium phosphate-synthetic resin-metal composite body. The calcium phosphate-synthetic resin-metal composite body may or may not contain a calcium phosphate block. The explanation below mainly concerns the production of a composite body containing a calcium phosphate block. A composite body containing no calcium phosphate block can also be obtained by a similar pressing/heating method.

10 (a) Production of the calcium phosphate block

The calcium phosphate block may be produced by known methods, but it is preferably produced by the methods described in JP 2-167868 A and JP 8-48583 A, foaming methods, and methods of adding thermally decomposable beads. The method for producing a calcium phosphate-synthetic resin composite body which is described in JP 2-167868 A, is a method (I) where a slurry or a fluid gel containing calcium phosphate compound powder and a polymer material is foamed and then thickened or gelled, and the resultant foamed body is sintered if necessary. The method for producing a calcium phosphate-synthetic resin composite body which is described in JP 8-48583 A, is a method (II) where polysaccharide particles and ceramic particles are mixed and compressed to form a green compact, which is sintered.

(b) Production of the calcium phosphate-synthetic resin-metal composite body

(I) Pressing/heating apparatus

25 Preferable pressing/heating methods for producing the calcium phosphate-synthetic resin-metal composite body include a method where a metal member, a mixture comprising the calcium phosphate particles and the synthetic resin particles I and II, and a calcium phosphate block are charged between a pair of dies connected to a heat source, which are heated while

applying pressure. The pressing/heating is preferably carried out under vacuum, or in an atmosphere of an inert gas such as N<sub>2</sub>, He and Ar.

Figs. 16 to 18 show an example of apparatuses for carrying out a pressing/heating treatment under vacuum or in an inert gas atmosphere. In Fig. 16, the pressing/heating apparatus 1 has a vacuum chamber 6 provided with a vacuum pump 7, a stationary die member 2 disposed therein, a pair of punches 4a and 4b for pressing a metal member, a mixture of calcium phosphate particles and synthetic resin particles I and II, and a calcium phosphate block introduced into a cavity 2a of the stationary die member 2 while heating, and rams 5a and 5b for driving the punches 4a and 4b. A thermocouple (not shown) for measuring the heating treatment temperature may be disposed in the stationary die member 2. A gas pump 11 is connected to a gas inlet member and a gas container (not shown).

Each ram 5a and 5b is driven by a press-driving mechanism 9 to press the mixture 3 while heating each punch 4a and 4b, with electric power received from a power supply 8 connected via a terminal (not shown). A control means 10 is connected to the press-driving mechanism 9, the power supply 8, the vacuum pump 7 and the thermocouple to control the heating temperature in the stationary die member 2, and degree of vacuum in the vacuum chamber 6.

As is shown in Fig. 17, the stationary die member 2 has an annular structure having a cavity 2a having a circular, oval or rectangular cross section. Each punch 4a and 4b has a slightly smaller cross section than the cavity 2a such that it can move up and down in the cavity 2a of the stationary die member 2. The punches 4a and 4b are secured to the rams 5a and 5b, respectively.

#### (II) Charging

The metal member, a mixture comprising the calcium phosphate particles and the synthetic resin particles I and II, and the calcium

phosphate block are charged into the cavity 2a of the stationary die member 2, such that the calcium phosphate particles and calcium phosphate block are exposed on at least part of the surface of the resultant composite body, and the synthetic resin particles I and II surround the calcium phosphate 5 particles.

The mass ratio of the calcium phosphate particles to the synthetic resin particles is preferably  $1/9$  to  $8/2$ . When the mass ratio of the calcium phosphate particles is more than  $8/2$ , the calcium phosphate particles may not be completely surrounded by the synthetic resin particles, resulting in easy 10 detachment of the calcium phosphate particles. On the other hand, when the mass ratio of the calcium phosphate particles is less than  $1/9$ , the ratio of calcium phosphate in the composite body may be too low, resulting in low biocompatibility.

For instance, when the calcium phosphate-synthetic resin-metal 15 composite body shown in Figs. 1(a) and (b) is produced, the metal member 200, the mixture 3a of the calcium phosphate particles and the synthetic resin particles I and II, and the calcium phosphate block 300 are charged into the cavity 2a of the stationary die member 2 shown in Fig. 16 in this order as is shown in Fig. 18. Alternatively, when the calcium phosphate-synthetic 20 resin-metal composite body shown in Fig. 10 or 11 is produced, a mixture 3 of the calcium phosphate particles and the synthetic resin particles I and II is charged into the cavity 2a to the height of about 5 to 10 mm, and a mesh- or plate-shaped metal member 200 is then put into the cavity 2a, as shown in Fig. 19(a). The mixture 3 is further added on the metal member 200 25 to a height of about 5 to 10 mm, as shown in Fig. 19(b). The mixture 3 enters into the meshes or through-holes 230 of the metal member 200. Thus, the step of charging materials into the die cavity 2a may be conducted depending on the structure of the calcium phosphate-synthetic resin-metal composite body to be produced.

(III) Pressing/heating treatment

In the case of the calcium phosphate-synthetic resin-metal composite body shown in Figs. 1(a) and (b), after the metal member 200, the mixture 3 and the calcium phosphate block 300 are charged into the cavity 2a in this order as is shown in Fig. 18, and the vacuum chamber 6 is sealed and evacuated by the vacuum pump 7 to a pressure of about 1 Pa. Thereafter, an inert gas such as N<sub>2</sub>, He or Ar may be introduced to carry out the pressing/heating treatment in a low oxygen concentration atmosphere, thereby preventing oxidative degradation of synthetic resin particles.

10        When the press-driving mechanism 9 is operated by the control means 10, at least one of the rams 5a and 5b moves in a direction to approach one another, so that the punches 4a and 4b secured thereto press the mixture 3. The pressing power of the punches 4a and 4b is preferably 0.5 to 50 MPa, and more preferably 1.0 to 20 MPa. When the pressing power is less than 0.5 MPa, 15 sufficient adhesion may not be achieved between the synthetic resin particles and the metal member, the synthetic resin particles and the calcium phosphate particles, and the synthetic resin particles and the calcium phosphate block, resulting in easy detachment of the metal member, the calcium phosphate particles and the calcium phosphate block from the resultant composite body. 20 At more than 50 MPa, however, correspondingly improved shape retention may not be obtained, and may result in problems such as the collapse of the calcium phosphate particles and the calcium phosphate block.

The punches 4a and 4b are heated by the power supply 8 to heat the mixture 3 under pressure. The mixture 3 is preferably heated according to 25 a predetermined temperature elevation program. In that case, the temperature of the mixture 3 is detected by a thermocouple (not shown) disposed in the stationary die member 2, and an output of the thermocouple is sent to the control means 10. The control means 10 produces a signal for temperature elevation according to the temperature elevation program on the basis of

input temperature data, and sends it to the power supply 8. The power supply 8 supplies appropriate current to the rams 5a and 5b according to a command from the control means 10.

The heating temperature is preferably 130°C to 300°C, and more preferably 150°C to 250°C. When the heating temperature is lower than 130°C, sufficient adhesion may not be achieved between the synthetic resin particles and the metal member, the synthetic resin particles and the calcium phosphate particles, and the synthetic resin particles and the calcium phosphate block, resulting in easy detachment of the metal member, the calcium phosphate particles and the calcium phosphate block from the composite body. A heating temperature higher than 300°C is not preferable, because the synthetic resin particles may not retain their shapes, sometimes resulting in integration by melting.

The heating time (time period in which the heating temperature is kept) is preferably 1 to 30 minutes. When the heating time is shorter than one minute, sufficient adhesion may not be achieved between the synthetic resin particles and the metal member, the synthetic resin particles and the calcium phosphate particles, and the synthetic resin particles and the calcium phosphate block. A heating time longer than 30 minutes is not preferable, because it may not provide improved adhesion. A more preferable heating time is 3 to 10 minutes.

After the pressing/heating treatment, the calcium phosphate-synthetic resin-metal composite body is cooled to room temperature, and removed from the stationary die member. When the calcium phosphate particles are not exposed sufficiently on the surface of the composite body, the surface may be ground.

(2) Second embodiment

The production of the cylindrical calcium phosphate-synthetic resin-metal composite body shown in Figs. 13 and 14 according to the second

embodiment is the same as that according to the first embodiment, except for charging a mixture 3 of calcium phosphate particles and synthetic resin particles I and II and a metal member 200 into the cavity 2a of the stationary die member 2. Thus, only the differences between the processes 5 will be explained below.

As shown in Fig. 20(a), a mixture 3 of the calcium phosphate particles and the synthetic resin particles I and II is charged into the cavity 2a of the stationary die member 2, such that the mixture 3 lies uniformly on a bottom surface of the cavity 2a. After the mixture 3 reaches 10 a height of about 5 to 10 mm, the metal member 200 is introduced into the cavity 2a, and the mixture 3 is further introduced into the cavity 2a so as to be present both inside and outside the metal member 200. Because the mixture 3 is charged outside the metal member 200, too, the inner size of the cavity 2a is about 3 to 10 mm larger than the outer size of the metal member 15 200.

As shown in Fig. 20(b), with the mixture 3 lying on the metal member 200 at a height of about 5 to 10 mm, the content in the cavity 2a is pressed while heating. The pressing/heating treatment provides a composite body 400 constituted by the metal member 200 and a calcium phosphate-synthetic resin 20 composite layer 3a covering the entire surface of the metal member 200, as shown in Figs. 21 and 22. This composite body 400 is left to cool to room temperature and then taken out from the molding die cavity. This composite body is a solid body comprising the metal member 200 embedded in the calcium phosphate-synthetic resin composite body, which may be called "metal member- 25 embedded composite body."

Fig. 22(a) is a side view showing a cylindrical metal member-embedded composite body 400, Fig. 22(b) is a cross-sectional view taken along the line L-L in Fig. 22(a), and Fig. 22(c) is a cross-sectional view taken along the line M-M in Fig. 22(a). The calcium phosphate-synthetic resin composite body

inside the metal member 200 is cut away from the solid metal member-embedded composite body to make it cylindrical, and the calcium phosphate-synthetic resin composite body is cut at positions corresponding to the windows of the metal member 200 to provide the cylindrical metal member-embedded composite body with openings 31. The calcium phosphate-synthetic resin composite body is cut away such that a calcium phosphate-synthetic resin composite layer 3a remains preferably in a thickness  $d$  of 0.5 to 2 mm on the inner and outer surfaces and the upper and lower end surfaces 222, 223 of the metal member 200. The cylindrical, windowed calcium phosphate-synthetic resin-metal composite body thus obtained comprises a cylindrical, windowed metal member 200 and a calcium phosphate-synthetic resin composite layer 3a formed on the entire surface of the metal member 200. The calcium phosphate-synthetic resin composite layer 3a is shown by the broken lines in Figs. 22(b) and 22(c).

15 (3) Third embodiment

Because of the special shape of the composite body shown in Figs. 15(a) and (b), it may be produced, for instance, as follows. To protect the thread 201 of the metal screw 200 during the molding process, a cylindrical metal cap 210 having a threaded hole 210b complementary to the thread 201, is inserted over the thread 201 as shown in Fig. 23. The depth of the threaded hole 210b of the metal cap 210 is determined such that an opened surface 210a of the metal cap 210 is aligned with the base surface 201a of the thread 201 when the thread 201 completely engages the threaded hole 210b. Because the metal cap 210 is removed from the metal screw 200 after molding, at least one of the thread 201 and the threaded hole 210b is preferably coated with a parting agent such as silicone for easy detachment.

Figs. 24 and 25 show an example of pressing/heating apparatus for producing the screw-shaped composite body shown in Fig. 15. Fig. 24 is a vertical cross-sectional view showing the molding die in an open state, and

Fig. 25 is a cross-sectional view taken along the line N-N in Fig. 24. This molding apparatus comprises a stationary die member 2 having a vertically penetrating cavity 2a with a rectangular cross section, a lower punch 4b entering into the cavity 2a of the stationary die member 2 from below, a protection die 12 entering into the cavity 2a of the stationary die member 2 from above to abut the lower punch 4b, and an upper punch 4a entering into the cavity 12a of the protection die 12 from above to abut the lower punch 4b. Driving rams 5a, 5b are attached to the punches 4a, 4b, respectively.

The lower punch 4b has a semicylindrical cavity 14b for receiving the metal screw 200 on a top surface. The semicylindrical cavity 14b is open at one end and closed at the other end in a longitudinal direction. The semicylindrical cavity 14b is positioned such that it is exposed to the cavity 2a of the stationary die member 2. The upper punch 4a has a semicylindrical cavity 14a having the same shape as that of the semicylindrical cavity 14b of the lower punch 4b at a position in alignment with the semicylindrical cavity 14b. Both semicylindrical cavities 14a and 14b have a shape substantially complementary to the cap 210 and the head 203 of the metal screw 200, respectively.

Figs. 26(a) to 26(e) show the protection die 12; Fig. 26(a) is a top view of the protection die 12, Fig. 26(b) is a cross-sectional view taken along the line O-O in Fig. 26(a), Fig. 26(c) is a cross-sectional view taken along the line P-P in Fig. 26(a), Fig. 26(d) is a cross-sectional view taken along the line Q-Q in Fig. 26(a), and Fig. 26(e) is a cross-sectional view taken along the line R-R in Fig. 26(a). The protection die 12 has a rectangular shape with such a size that it is accurately received in the cavity 2a of the stationary die member 2. The protection die 12 comprises a cavity 12a vertically penetrating therethrough and having the same rectangular shape as the outer shape of the upper punch 4a as shown in Fig. 26(a); and semicylindrical cavities 12b, 12c extending in the longitudinal

direction of the cavity 12a as shown in Figs. 26(b) to 26 (e). The semicylindrical cavities 12b and 12c have complementary shapes to the metal screw 200 provided with the cap 210. The longitudinally aligned semicylindrical cavities 12b and 12c receive the metal screw 200 at an accurate position in cooperation with the semicylindrical cavity 14b of the lower punch 4b. The semicylindrical cavity 12c exactly has a length for accommodating the screw head 203 (length equal to the thickness of the screw head 203), functioning as a protector for the screw head 203 when the metal screw 200 is set in the die cavity 2a.

Described below is an example of the production of the screw-shaped composite body shown in Fig. 15 by using the apparatus having the structure shown in Figs. 24 to 26. First, as shown in Fig. 27, with the metal screw 200 provided with the cap 210 placed in the semicylindrical cavity 14b of the lower punch 4b, the lower punch 4b is moved upward and is stopped around a center of the cavity 2a of the stationary die member 2. The protection die 12 is then moved down in this state, until the semicylindrical cavities 12b and 12c of the protection die 12 mate the semicylindrical cavity 14b of the lower punch 4b to provide a cylindrical cavity, in which the cap 210 and the screw head 203 are fixed.

In this state, the mixture 3 of the calcium phosphate particles and the synthetic resin particles I and II is charged into the cavity 14b of the lower punch 4b and the cavity 12a of the protection die 12. As shown in Fig. 28(a), the upper punch 4a is moved down through the cavity 12a of the protection die 12 to press the mixture 3 while heating, so that the resultant calcium phosphate-synthetic resin composite body adheres to the metal member (metal screw body) 200. Fig. 28(b) shows a state where the molding is completed.

After the completion of molding, as shown in Fig. 29, the upper and lower punches 4a, 4b and the protection die 12 are moved outward from the

stationary die member 2, and the resultant screw-shaped composite body comprising the metal screw 200 and the calcium phosphate-synthetic resin composite layer 3a adhering to the metal screw 200 is removed from the lower punch 4b. As shown in Fig. 30, the calcium phosphate-synthetic resin composite layer 3a adheres only to the screw trunk 202 but not to the cap 210 and the head 203. Accordingly, the cap 210 can be easily detached from the metal screw 200 by rotation. The detached cap 210 is reused in subsequent molding steps after recoating with a parting agent.

As shown in Fig. 31, with the head 203 gripped, the calcium phosphate-synthetic resin composite body around the trunk 202 is ground to a screw shape. The calcium phosphate-synthetic resin composite body 3a is ground in a limited area slightly inside the head 203 to allow for grinding errors. Though some of the calcium phosphate-synthetic resin composite body 3a is left on the inside surface of the head 203, it can easily be removed.

15

#### Example 1

10 g of calcium phosphate powder having an average particle diameter of 30  $\mu\text{m}$  was added to 20 g of an aqueous solution containing 1% by mass of methylcellulose, and blended at a predetermined speed for a predetermined period of time. The resultant foamed slurry was molded in a molding die frame, dried at 80°C for 72 hours and then sintered in an air furnace at 1200°C for 4 hours. Machining was carried out to provide a calcium phosphate block 300 having a calcium/phosphorus molar ratio of 1.67, an outer shape of 20 mm in diameter and 4 mm in thickness and a porosity of 45%.

25 10.0 g of porous calcium phosphate particles 100 having particle diameters of 0.2 to 0.6 mm and a calcium/phosphorus molar ratio of 1.67, which was sintered in an air furnace at 1200°C, 4.0 g of cross-linked acrylic powder I having an average particle diameter of 3.0  $\mu\text{m}$  (Chemisnow MX-300 available from Soken Chemical & Engineering Co., Ltd.), and 1.0 g of uncross-

linked acrylic powder II having an average particle diameter of 1.5  $\mu\text{m}$  (Chemisnow MP-1400 available from Soken Chemical & Engineering Co., Ltd.) were mixed.

To obtain a calcium phosphate-synthetic resin-metal composite body 5 having the structure shown in Fig. 1, a circular stainless steel plate 200 (20 mm in diameter and 8 mm in thickness), 2.2 g of a mixture of the porous calcium phosphate particles 100 and the synthetic resin particles I and II, and a circular, plate-like, porous calcium phosphate block 300 (20 mm in diameter x 4 mm in thickness) were charged into the cavity 2a of the 10 stationary die member 2 (20 mm in internal diameter x 50 mm in height) in the pressing/heating apparatus shown in Figs. 16 to 18. The mixture in the die cavity 2a was kept at a temperature of 240°C for 10 minutes while pressing at a pressure of 10 MPa from above and below. It was then cooled, and the pressure was released at room temperature.

15 The resultant calcium phosphate-synthetic resin-metal composite body was machined by a lathe to obtain a composite body with a diameter of 20 mm and a thickness of 15.7 mm. Observation of a surface of the calcium phosphate-synthetic resin composite layer 3a of this composite body by a scanning electron microscope revealed that the calcium phosphate was exposed 20 on the surface without being covered with the acrylic resin.

#### Example 2

To obtain a calcium phosphate-synthetic resin-metal composite body having the structure shown in Fig. 2, a sintered body was prepared in the 25 same manner as in Example 1, except for changing the blending speed and mixing time of the aqueous methylcellulose solution and calcium phosphate powder. The sintered body was machined to produce a cylindrical, porous calcium phosphate block 300 having a molar ratio of calcium to phosphorus of 1.67 with an external diameter of 20 mm, an internal diameter of 16 mm and

a thickness of 15 mm and with a porosity of 30%.

The above cylindrical, porous calcium phosphate block 300, a stainless steel column 200 (10 mm in diameter x 15 mm in thickness), and 3.40 g of a mixture of porous calcium phosphate particles and the synthetic resin particles I and II, which was obtained in the same manner as in Example 1, were charged into the cavity 2a of the stationary die member 2 (20 mm in internal diameter x 50 mm in height) of the pressing/heating apparatus shown in Figs. 16 to 18. The content in the cavity 2a of the stationary die member 2 was kept at a temperature of 200°C for 5 minutes while pressing at a pressure of 5 MPa from above and below. It was then cooled, and the pressure was released at room temperature.

The resultant calcium phosphate-synthetic resin-metal composite body was machined by a lathe to obtain a composite body with a diameter of 20 mm and a thickness of 15 mm. Observation of a surface of the calcium phosphate-synthetic resin composite layer 3a of this composite body by a scanning electron microscope revealed that the calcium phosphate was exposed on the surface without being covered with the acrylic resin.

#### Example 3

To obtain a calcium phosphate-synthetic resin-metal composite body having the structure shown in Fig. 9, a cylindrical stainless steel member 200 (15 mm in external diameter, 10 mm in internal diameter, 10 mm in thickness), and 1.40 g of a mixture of the porous calcium phosphate particles and the synthetic resin particles I and II, which was obtained in the same manner as in Example 1, were charged into the cavity 2a of the stationary die member 2 (15 mm in internal diameter x 30 mm in height) of the pressing/heating apparatus shown in Figs. 16 to 18. The content in the molding die cavity 2a was kept at a temperature of 180°C for 10 minutes while pressing at a pressure of 10 MPa from above and below. It was then cooled,

and the pressure was released at room temperature.

The calcium phosphate-synthetic resin composite layer 3a adhering to the top surface of the cylindrical stainless steel member 200 was removed by machining to obtain the composite body. Observation by a scanning electron microscope revealed that the calcium phosphate was exposed on the surface without being covered with the acrylic resin.

#### Example 4

To produce a bone-connecting screw used as a biomaterial, as shown in Fig. 15, a cap 210 (7.0 mm in external diameter, 10.0 mm in entire length) was put onto a thread 201 of a stainless steel screw 200 (6.0 mm in external diameter at the root of a thread 201, 30.0 mm in entire length, 3.0 mm in external diameter of a trunk 202, 7.0 mm in external diameter of a head 203), as shown in Fig. 23. With the stainless steel screw 200 provided with the cap 210 placed in a semicylindrical cavity 14b (32.0 mm in length x 3.5 mm in radius) of a lower punch 4b, the lower punch 4b was moved up, so that the stainless steel screw 200 was fixed around the center in the cavity 2a of the stationary die member 2 of the pressing/heating apparatus. In the state shown in Fig. 27, a protection die 12 was moved down to abut the cap 210, and 1.30 g of a mixture of the porous calcium phosphate particles and the synthetic resin particles I and II, which was obtained in the same manner as in Example 1, was then charged into the cavity 14b of the lower punch 4b and in the cavity 12a of the protection die 12.

As shown in Fig. 28, the upper punch 4a was moved down, and the mixture 3a charged into the cavity 2a was kept at a temperature of 200°C for 10 minutes while pressing at a pressure of 10 MPa. The mixture 3a was then cooled, and the upper and lower punches and the protection die 12 were moved outside the stationary die member 2 to take out the resultant molded product.

After the cap 210 was detached from the molded product as shown in Fig. 30, the calcium phosphate-synthetic resin composite layer 3a was machined to a screw shape as shown in Fig. 31 to obtain the composite body shown in Fig. 15. Observation of a surface of the calcium phosphate-synthetic resin composite layer 3a of this composite body by a scanning electron microscope revealed that the calcium phosphate was exposed on the surface without being covered with the acrylic resin.

#### Example 5

##### 10 (1) Preparation of mixture

10 g of porous calcium phosphate particles 100 having an average particle diameter of 0.2 to 0.6 mm and a calcium/phosphorus molar ratio of 1.67, which was sintered in an air furnace at 1,200°C, 4 g of cross-linked acrylic powder I having an average particle diameter of 3  $\mu$ m (Chemisnow MX-15 300 available from Soken Chemical & Engineering Co., Ltd.), and 1 g of uncross-linked acrylic powder II having an average particle diameter of 1.5  $\mu$ m (Chemisnow MP-1400 available from Soken Chemical & Engineering Co., Ltd.) were mixed.

##### (2) Charging into molding die

20 As shown in Fig. 20, the mixture 3 prepared in the above step (1) was charged into the cavity 2a (24 mm x 14 mm x 50 mm in height) of the stationary die member 2 in the pressing/heating apparatus to a height of approximately 7 mm, a titanium member 200 (20.0 mm x 10.0 mm x 15 mm in height, 2.0 mm in thickness) having the structure shown in Fig. 12 having 25 windows (5.0 mm x 8.0 mm) was placed on the mixture 3, and then the rest of the mixture 3 was charged into the cavity 2a such that it entered into space inside and outside the titanium member 200. The titanium member 200 was thus embedded in the mixture 3.

##### (3) Pressing/heating treatment

The content in the cavity 2a was kept at a temperature of 200°C for 5 minutes while pressing from above and below at a pressure of 10 MPa, and then cooled to room temperature, and the pressure was released. In the resultant cylindrical metal member-embedded composite body 400, the metal member 200 was filled with the calcium phosphate-synthetic resin composite body without gaps. The calcium phosphate-synthetic resin composite body of the cylindrical metal member-embedded composite body 400 was machined to the calcium phosphate-synthetic resin composite layer 3a having a thickness of about 1 mm by a milling machine with a machining center, thereby providing the calcium phosphate-synthetic resin-metal composite body (22.0 mm x 12.0 mm x 17 mm in height, 4.0 mm in thickness) having windows (3.0 mm x 6.0 mm) as shown in Figs. 13 and 14. Observation of a surface of the calcium phosphate-synthetic resin composite layer 3a of this composite body by a scanning electron microscope revealed that the calcium phosphate was exposed on the surface without being covered with the acrylic resin. Because the metal member was completely covered with the calcium phosphate-synthetic resin composite layer, it was not exposed on the surface of the composite body.

#### 20 Example 6

##### (1) Preparation of mixture

6 g of the porous calcium phosphate particles 100 having an average particle diameter of 0.1 to 0.3 mm and a calcium/phosphorus molar ratio of 1.50, which was sintered in an air furnace at 700°C, 6 g of cross-linked acrylic powder I having an average particle diameter of 3  $\mu$ m (Chemisnow MX-300 available from Soken Chemical & Engineering Co., Ltd.), and 0.5 g of uncross-linked acrylic powder II having an average particle diameter of 1.5  $\mu$ m (Chemisnow MP-1400 available from Soken Chemical & Engineering Co., Ltd.) were mixed.

(2) Charging into molding die

After the mixture 3 prepared in step (1) was charged into the cavity 2a (30 mm x 40 mm x 30 mm in height) of the stationary die member 2 of the pressing/heating apparatus to a height of approximately 6 mm, a titanium net 5 (wire diameter: 1.0 mm, 8 meshes, 25.0 mm x 35.0 mm) was placed thereon, and the rest of the mixture 3 was added thereon.

(3) Pressing/heating treatment

The content in the cavity 2a was kept at a temperature of 200°C for 5 minutes while pressing at a pressure of 10 MPa from above and below. It 10 was then cooled, and the pressure was released at room temperature. The resultant calcium phosphate-synthetic resin composite body was worked by a milling machine to a calcium phosphate-synthetic resin composite layer 3a of about 1 mm in thickness, thereby obtaining a calcium phosphate-synthetic resin-metal composite body shown in Fig. 10 (27.0 mm x 37.0 mm x 2.5 mm in 15 thickness). Observation of a surface of the calcium phosphate-synthetic resin composite layer 3a of this composite body by a scanning electron microscope revealed that the calcium phosphate was exposed on the surface without being covered with the acrylic resin. This composite body was sterilized at 121°C for 20 minutes in an autoclave. The three-point bending 20 strength of this calcium phosphate-synthetic resin-metal composite body was 77.6 MPa. Because the metal member was completely covered with the calcium phosphate-synthetic resin composite layer, it was not exposed on the surface of the body.

25 Comparative Example 1

A calcium phosphate-synthetic resin composite body was produced in the same manner as in Example 6 except for using no titanium net. The three-point bending strength of the resultant composite body was 25.5 MPa.

As described above, the calcium phosphate-synthetic resin-metal

composite body of the present invention has high biocompatibility and mechanical strength, because the calcium phosphate particles and/or the calcium phosphate block having excellent biocompatibility are exposed on at least part of the surface of the composite body, and because it comprises a  
5 metal member having excellent mechanical strength. The calcium phosphate-synthetic resin-metal composite body of the present invention having such a structure has excellent workability, biocompatibility, water resistance and impact resistance, and is suitable for artificial dental roots, bone reinforcements, etc.

WHAT IS CLAIMED IS:

1. A calcium phosphate-synthetic resin-metal composite body produced by pressing a metal member, a calcium phosphate block and a mixture of calcium phosphate particles, synthetic resin particles I, which are at least partially cross-linked in advance, and uncross-linked, synthetic resin particles II while heating, said calcium phosphate particles and/or said calcium phosphate block being exposed on at least part of the surface of said composite body.
2. A calcium phosphate-synthetic resin-metal composite body according to claim 1, wherein said synthetic resin particles I and II are bonded to said metal member, said calcium phosphate particles and said calcium phosphate block.
3. A calcium phosphate-synthetic resin-metal composite body according to claim 1 or 2, wherein said calcium phosphate-synthetic resin-metal composite body comprises a calcium phosphate-synthetic resin composite layer composed of said calcium phosphate particles and said synthetic resin particles I and II, which covers the entire surface of said metal member.
4. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 1 to 3, wherein said metal member comprises at least one metal or alloy selected from the group consisting of pure titanium, titanium alloys and stainless steel.
5. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 1 to 4, wherein said synthetic resin particles I and II comprise a water-insoluble acrylic or polystyrene resin.
6. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 1 to 5, wherein said calcium phosphate particles and/or said calcium phosphate block are sintered.
7. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 1 to 6, wherein said calcium phosphate particles and said

calcium phosphate block are porous.

8. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 1 to 7, wherein at least part of said metal member has a thickness of 0.5 mm or more.
- 5 9. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 1 to 8, wherein the content of said synthetic resin particles II is 0.2 to 50% by mass based on the total amount of said synthetic resin particles I and II.
10. A calcium phosphate-synthetic resin-metal composite body according to  
10 any one of claims 1 to 9, wherein the mass ratio of said calcium phosphate particles to said synthetic resin particles is 1/9 to 8/2.
11. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 1 to 10, wherein the calcium/phosphorus molar ratio in said calcium phosphate particles and said calcium phosphate block is 1.4 to 2.0.
- 15 12. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 1 to 11, wherein said calcium phosphate particles have an average particle size of 0.001 to 10 mm.
13. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 1 to 12, wherein said calcium phosphate block has a  
20 thickness of 1 mm or more.
14. A calcium phosphate-synthetic resin-metal composite body produced by pressing a metal member and a mixture of calcium phosphate particles, synthetic resin particles I, which are at least partially cross-linked in advance, and uncross-linked, synthetic resin particles II while heating, said  
25 calcium phosphate particles being exposed on at least part of the surface of said composite body.
15. A calcium phosphate-synthetic resin-metal composite body according to claim 14, wherein said synthetic resin particles I and II are bonded to said metal member and said calcium phosphate particles.

16. A calcium phosphate-synthetic resin-metal composite body according to claim 14 or 15, wherein said calcium phosphate-synthetic resin-metal composite body comprises a calcium phosphate-synthetic resin composite layer composed of said calcium phosphate particles and said synthetic resin particles I and II, which covers the entire surface of said metal member.
17. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 14 to 16, wherein said metal member comprises at least one metal or alloy selected from the group consisting of pure titanium, titanium alloys and stainless steel.
18. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 14 to 17, wherein said synthetic resin particles I and II comprise a water-insoluble acrylic or polystyrene resin.
19. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 14 to 18, wherein said calcium phosphate particles are sintered.
20. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 14 to 19, wherein said calcium phosphate particles are porous.
21. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 14 to 20, wherein at least part of said metal member has a thickness of 0.5 mm or more.
22. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 14 to 21, wherein the content of said synthetic resin particles II is 0.2 to 50% by mass based on the total amount of said synthetic resin particles I and II.
23. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 14 to 22, wherein the mass ratio of said calcium phosphate particles to said synthetic resin particles is 1/9 to 8/2.
24. A calcium phosphate-synthetic resin-metal composite body according to

any one of claims 14 to 23, wherein the calcium/phosphorus molar ratio in said calcium phosphate particles is 1.4 to 2.0.

25. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 14 to 24, wherein said calcium phosphate particles have an  
5 average particle size of 0.001 to 10 mm.

26. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 14 to 25, wherein said metal member has a hollow shape; and wherein said calcium phosphate-synthetic resin composite layer covers the entire surface of said metal member.

10 27. A calcium phosphate-synthetic resin-metal composite body according to claim 26, wherein said metal member has windows at which said calcium phosphate-synthetic resin composite layer is open.

28. A calcium phosphate-synthetic resin-metal composite body according to any one of claims 14 to 27, wherein said calcium phosphate-synthetic resin-  
15 metal composite body has a screw shape; and wherein a calcium phosphate-synthetic resin composite layer composed of said calcium phosphate particles and said synthetic resin particles I and II is formed on a trunk of said metal member.

29. A method for producing the calcium phosphate-synthetic resin-metal  
20 composite body recited in any one of claims 1-28 comprising the steps of (a) introducing said metal member, said calcium phosphate particles (or said calcium phosphate particles and said calcium phosphate block), and said synthetic resin particles I and II into a cavity of a molding die, such that said synthetic resin particles surround said calcium phosphate particles, and  
25 that said calcium phosphate particles and/or said calcium phosphate block are exposed on at least part of the surface of said composite body; and (b) pressing them in said molding die cavity while heating, so that said synthetic resin particles are bonded to said metal member and said calcium phosphate particles (or said calcium phosphate particles and said calcium

phosphate block).

30. A method for producing a calcium phosphate-synthetic resin-metal composite body according to claim 29, wherein said metal member and a mixture of said calcium phosphate particles and said synthetic resin particles I and 5 II are introduced into said cavity of said molding die such that said mixture surrounds said metal member.

31. A method for producing a calcium phosphate-synthetic resin-metal composite body according to claim 29 or 30 further comprising the step of sintering said calcium phosphate particles and/or said calcium phosphate 10 block in advance.

32. A method for producing a calcium phosphate-synthetic resin-metal composite body according to claim 31, wherein the sintering temperature of said calcium phosphate particles and said calcium phosphate block is 500°C to 1,300°C.

15 33. A method for producing a calcium phosphate-synthetic resin-metal composite body according to any one of claims 29 to 32, wherein said pressing/heating step is carried out under vacuum, or in an atmosphere containing no oxygen.

34. A method for producing a calcium phosphate-synthetic resin-metal 20 composite body according to any one of claims 29 to 33, wherein said metal member is hollow; the method including the steps of heating said hollow metal member filled with a mixture of said calcium phosphate particles and said synthetic resin particles I and II while pressing to provide a metal member-embedded composite body comprising said metal member filled with a calcium 25 phosphate-synthetic resin composite body; cutting away part of said calcium phosphate-synthetic resin composite body in said metal member-embedded composite body to make a hollow calcium phosphate-synthetic resin-metal composite body.

35. A method for producing a calcium phosphate-synthetic resin-metal

composite body according to claim 34, comprising using a metal member having windows; and grinding said calcium phosphate-synthetic resin composite body at positions corresponding to said windows to provide a calcium phosphate-synthetic resin-metal composite body with windows.

5 36. A method for producing a calcium phosphate-synthetic resin-metal composite body according to any one of claims 29 to 35, comprising using a screw-shaped metal member; placing said screw-shaped metal member in a cavity of said molding die with a cap mounted on a thread of said metal member; charging a mixture of said calcium phosphate particles and said synthetic  
10 resin particles I and II into said die cavity; pressing said mixture while heating to form a calcium phosphate-synthetic resin composite body around said metal member; removing said cap from said screw-shaped metal member; and machining said calcium phosphate-synthetic resin composite body around a trunk of said metal member to provide a calcium phosphate-synthetic resin-  
15 metal composite body with a threaded portion.

37. A method for producing a calcium phosphate-synthetic resin-metal composite body according to claim 36, comprising using a molding die comprising a stationary die member having a cavity penetrating in a vertical direction; a lower punch having a cavity for receiving a screw-shaped metal  
20 member provided with a cap and entering into the cavity of said stationary die member from below; a protection die having a cavity penetrating in a vertical direction and a cavity for receiving a head and said cap of said screw-shaped metal member provided with a cap and abutting said lower punch; and a vertically movable upper punch having a cavity having the same shape  
25 as that of said cavity of said lower punch at a position aligned with said cavity of said lower punch, and entering into the vertical cavity of said protection die from above to abut said lower punch.

38. A method for producing a calcium phosphate-synthetic resin-metal composite body according to claim 37, comprising placing said lower punch in

said cavity of said stationary die member after said screw-shaped metal member provided with said cap is placed on said cavity of the lower punch; moving said protection die downwards so that said cavity of the protection die abuts said cavity of the lower punch; charging a mixture of said calcium phosphate particles and said synthetic resin particles I and II into the cavities of said lower punch and said protection die; and moving said upper punch downwards to press said mixture while heating, thereby forming a layer of a calcium phosphate-synthetic resin composite body on a trunk of said metal member.

39. A calcium phosphate-synthetic resin-metal composite body which comprises a metal member, calcium phosphate particles, synthetic resin particles I, which are at least partially cross-linked in advance, and uncross-linked synthetic resin particles II, said calcium phosphate particles being exposed on at least part of the surface of said composite body, and wherein said synthetic resin particles I and II are bonded to said metal member and said calcium phosphate particles.

40. A calcium phosphate-synthetic resin-metal composite body according to claim 39 which further comprises a calcium phosphate block to which said synthetic resin particles I and II are bonded.

41. A calcium phosphate-synthetic resin-metal composite body substantially as hereinbefore described with reference to the accompanying drawings.

42. A method for producing a calcium phosphate-synthetic resin-metal composite body substantially as hereinbefore described with reference to the accompanying drawings.



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Application No: GB 0317023.0  
Claims searched: 1-42

Examiner: Dave McMunn  
Date of search: 11 December 2003

## Patents Act 1977 : Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
Y	14-22, 39	EP 0,962,215 A2 (GC DENTAL). Note use of both cross-linked & non cross-linked polymers
Y	14-22, 39	IE 920833 (BAYER). Note use of both cross-linked & non cross-linked polymers. See also prior art referred to on pages 1-3
Y	14-22, 39	EP 0,205,333 A1 (KUREHA). Note metallic core & use of methacrylates with hydroxyapatite
Y	14-22, 39	GB 2,216,013 A (MITSUBISHI). Note metallic core & use of methacrylates with calcium hydroxide
Y	14-22, 39	GB 2,010,095 A (GUIDO REISS). Note metallic core & use of methacrylates with calcium hydroxide
A		JP 63279835 A (NIHON KENTETSU). Note metallic core & use of resins with hydroxyapatite

### Categories:

X Document indicating lack of novelty or inventive step	A Document indicating technological background and/or state of the art
Y Document indicating lack of inventive step if combined with one or more other documents of same category.	P Document published on or after the declared priority date but before the filing date of this invention.
& Member of the same patent family	E Patent document published on or after, but with priority date earlier than, the filing date of this application.

### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>V</sup>:

A5R, B5A.

Worldwide search of patent documents classified in the following areas of the IPC<sup>7</sup>:

A61K

The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC, JAPIO.

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